What is Heat?

A PEEP INTO NATURE'S MOST HIDDEN SECRETS.

FREDERICK HOVENDEN, F.L.S., F.G.S., F.R.M.S.

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A Peep into Nature's Most Hidden Secrets.

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BY

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PREFACE.

PROFESSOR HUXLEY, in his " Lay Sermons, Addresses, and Reviews," states: "*A fortiori*, the phenomena of "biology and of chemistry are, in their ultimate analysis, "questions of molecular physics. Indeed, the fact is "acknowledged by all chemists and biologists who look "beyond their immediate occupations." In other words, the sequence of phenomena, which we recognise in the individual existence, and which we call " Life," is solely molecular phenomena—*i.e.*, energy of molecules. It must follow, therefore, to understand life, we must understand the factors which cause molecular energy. The two principal ones are Heat and Electricity. The problems of the day are: to understand these factors, which operate on all things around us as well as on our own individuality.

This essay is a contribution towards solving these difficult problems. The questions are dealt with in a novel manner, and it is thought that it would be better to attack the question, " What is Heat ? " in the first instance. If this work makes its mark, an effort will be made to follow with the solutions of the further problems, " What is Electricity ? " and " What is Life ? " This latter responds to the questions: " What are we,

"where are we, from whence did we come, and whither do "we go?" Science has probably sufficiently advanced to solve these problems.

If the ideas here enunciated are true, the views of Life arising from them will be found of supreme importance. Every action of the human being will be seen from a new point of view, and there can be little doubt a new order of conduct will be the result. And why? Because the actions of the human being generally deal only with effects, and disregard causes. In the present strained condition of things, the consideration of these problems is urgent—imperative; it transcends all other serious thoughts.

No effort has been made to make the work a high-class literary composition, but rather to tell a very complex tale in the simplest manner, so that the layman may fully grasp the issues. In the main it is by him the verdict will be given, and it is to him the issues are of the greatest importance.

The Author is indebted to his friend Mr. Douglas Neale for the interest he has shown in assisting to work out the experiments; to his engraver, Mr. Robert Paterson, for the patient care he has taken to illustrate them; and to Mr. R. W. Frazer, LL.B., for his kind suggestions during the passage of the work through the press.

It is advisable, after reading the Preface, and before reading the Book, to read the "Conclusion," p. 346, as it gives a greater grasp of the important objects of the work.

ERRATA.

Page 46—Last line, should read "consists of a group of" instead of "of groups of"

,, 68—18th line, "loose" should read "lose"

,, 109—Foot note, 5th line, "experiments" should read "experiment"

,, 124—6th line, (§ 174) should read (§ 175)

,, 192—21st line, "spirits of wine" should read "spirit of wine"

,, 231—14th line, (§ 80, *5*) should read (§ 81, *5*)

,, 267—2nd line, "*e*" should read "*f*"

CONTENTS.

PART FIRST.

INTRODUCTION—ON MATHEMATICAL AND PHYSICAL CONCEPTS.

PART SECOND.

ON THE KINETIC THEORY.

PART THIRD.

ON GRAVITATION AND WEIGHT.

PART FOURTH.

STATEMENT OF THE CASE.

THE LAWS RELATING TO MATTER.

PART FIFTH.

ON HEAT.

I.

VI.

VII.

VIII.

IX.

PART I.

INTRODUCTION—ON MATHEMATICAL AND PHYSICAL CONCEPTS.

WHAT IS HEAT?

PART I.

INTRODUCTION—ON MATHEMATICAL AND PHYSICAL CONCEPTS.

" *The utter anarchy which notoriously prevails in the dis-*
" *cussion of ultimate scientific questions, so called, indi-*
" *cates that a determination of the proper attitude of*
" *scientific enquiry towards its objects is the most pressing*
" *intellectual need of our time, as it is an indispensable*
" *prerequisite of real intellectual progress at all times.*"*

1. What is Heat? And, what is Electricity? Whenever a wire conducting electricity gives resistance there is a lateral leakage, and that leakage is expressed in terms of "Heat," and the Heat evolved is always in exact ratio to the resistance. Are Heat and Electricity the same? † Every phenomenon of life is attended with

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* "The Concepts and Theories of Modern Physics." By J. B. Stallo. 2nd edition, 1885, p. 10.

† "The exact mode of conduction of heat is unknown, but, " whatever it is, it can hardly be doubted that the conduction of " electricity through metals is not very unlike it, for the two processes

Electrical and Heat reactions. Prof. Dewar has, recently, so completely extracted Heat from Oxygen Gas that it has been rendered inert—the Gas becomes a liquid, it sleeps; that is, it will not combine with other matter, yet it is in intense molecular motion—it boils! Our sensations of Heat or Cold are so well marked, so ever recurring, that the question of temperature—whatever this term may mean*—is the constant topic of conversation. Yet we cannot, at present, solve the problem—What is Heat? The bare fact that the motion of the being—life, depends upon Heat makes the problem, probably, the grandest that man can solve.

"The aspects of Nature provoke in man the spirit "of enquiry. As the eye is made for seeing, and the "ear for hearing, so the human mind is formed for "exploring and understanding the relationship of natural "phenomena, the Science of our day being the direct "issue of an intellect thus endowed. One great "characteristic of Natural Knowledge is its growth; all "its results are fruitful, every new discovery becoming "instantly the germ of fresh investigation. But no "nobler example of this growth can be adduced than "the expansion and development, during the last five-

---

"obey the same laws of propagation: they are both of the nature of "a diffusion, they both obey Ohm's law, and a metal which conducts "heat well conducts electricity well also."—"Modern Views of Elec-"tricity," by Prof. Oliver J. Lodge, LL.D., F.R.S. 1892, p. 78.

* "There are few scientific terms more difficult to define than "this common word, temperature."—"The New Chemistry," by J. P. Cooke, LL.D. 10th edition, 1892, p. 39.

"and-twenty years, of the great subject which is now "to occupy our attention . . . the subject is "an entangled one, and, in the pursuit of it, we must "be prepared to encounter difficulties. In the whole "range of Natural Science, however, there are none "more worthy of being overcome—none the subjugation "of which ensures a greater reward to the worker. "For the various agencies of Nature are so connected, "that in mastering the laws and relations of Heat, we "make clear to our minds the interdependence of "natural powers generally."*

2. By common consent the solutions of the fundamental problems—What is Heat? and What is Electricity? are placed in the hands of the physicist. The physicist, in great part, derives his fundamental notions from mathematical concepts. Mathematical concepts are metaphysical—pure and simple. What are these metaphysical ideas?

3. The result obtained by the mode adopted by the physicist is unsatisfactory, for all parties agree (including the physicist) that the kinetic or dynamical theory of Heat, which is based on mathematical notions, must be held as a useful temporary theory only. Thus we are as far from the real solutions of the problems What is Heat? and also What is Electricity? as we ever were.

* "Heat, a Mode of Motion," by John Tyndall, D.C.L. 4th edition, 1870, p. 1. [We venture to think it is a pity the late Dr. Tyndall eliminated this beautiful introduction in his last edition.]

4. The achievements of the physicist—the mathematician—have been very great; no doubt the community owes to him very much. Emboldened by his successes, he, however, often assumes an infallible position—he regards his mode of reasoning as perfect, and his notions beyond all question. We, however, are not disposed to put our full faith in the metaphysician's or mathematician's concepts. If his ideas were real, the physicist should be able to solve the problems under consideration, but he cannot. It is possible that the solutions are as far beyond the knowable as are the dimensions of space, or the beginning and end of eternity. We, however, do not think these problems are beyond solution. They cannot, we believe, be solved by mathematics, but only by means of experiment.

5. The task we have set ourselves is a difficult one. And to clear the way, for the reasons given in § 27 and § 40, it is absolutely necessary we should begin by obtaining clear definite fundamental ideas. In order to get these we must question mathematical notions. This we proceed to do.

6. The foundation of mathematics is arithmetic. Arithmetic is the science of numbers. What is a number?* Let us start with the numeral 1. What is

* "The terms 'abstract and concrete numbers' are also "fallacious and misleading. Numbers, in themselves, are essen-"tially abstract. In another sense they are essentially concrete; "they always stand for some particular object, relation, or opera-

meant by this figure? This unit conveys no idea by itself. The general reply would be: It represents an or "*one*" object; or a process, as the act of doing an operation *once*: as, for instance, bringing an object from one place to another "*one*" time, or the pull to the earth as "*one*" pound weight, or the measure of distance as "*one*" inch, or the measure of volume as "*one*" pint. But remark, we cannot have the operation of moving without the object to be moved. We cannot have the pull of the weight without the object weighed. We cannot have the measure of distance nor the measure of volume without objects to be measured. All operations are functions of objects, and without objects there could not be operations. Our first step, therefore, is to apply the science of mathematics to objects; and for our purpose it is sufficient if we confine ourselves to objects, and test the science of mathematics by seeing how far their formulæ apply to them. If the foundation is defective, how about the superstructure? If, therefore, the foundations of mathematics are unreal, can we wonder that ideas formed from such data cannot be found to solve these great problems of the day which we have under consideration?

"tion. They are nothing in themselves."—"The Concepts and Theories of Modern Physics," by J. B. Stallo. 2nd edition, 1885, p. 266.

"Numbers are not absolute notions, but arbitrary designations "for one or more objects."—"On Innate Ideas." Dr. Louis Büchner.

7. But we are brought face to face with the question, What is an object? We take a table. We call that an object. The table, however, is built up of parts—they are objects. We make a section of a piece of the wood, it is built up of parts—cells, they are objects. These parts are given to the chemist, and he resolves them into atoms, and they also are objects. We can go no further. Thus we are driven, in our definition of the unit, point by point, to the deduction that the only true fundamental unit or object is the finite particle chemistry points to — the atom, and that all other objects are groups or combinations of these objects—atoms.

8. This reasoning is very simple. The mathematician cannot object to it; and if it ended thus, all would be easy. We therefore adhere to the notion that the finite particle—the atom, is the true natural unit, and all other units are compound, *i.e.*, are aggregations of true units. Now comes in the mathematical idea, and it is this: The unit can be divided into fractions *ad infinitum*. If the unit is the *finite* particle, we fail to see that the metaphysician has a power to divide it. He may *imagine* he can do it; it may be even advantageous he should so imagine his powers, and while he adheres to the fact that such concepts are not real, but existing solely in the mathematician's brain, no harm can ensue.

The indestructibility of the atom—or conservation of matter, besides being proved by experiment, is so clear

and harmonious with our natural reasoning that one wonders how any other view could exist or have existed.

The idea that atomic matter can be divided *ad infinitum* implies that the ultimate particle can be divided into space—divided into nothing. This is another way of expressing the power of the mathematician as equal to a capacity to annihilate matter.

9. We will, as a next step, take algebraical symbols and apply them to the true unit—the atom. We must bear in mind that algebra is only "That branch of "analysis whose object is to investigate the relations and "properties of numbers by means of letters and other "symbols" (Webster's Dictionary). Hence algebra has no meaning until we find the value of the symbol by means of number, and a number has no meaning until we apply it to an object or process. What therefore applies to arithmetic applies to algebra, and contrariwise. So then our a b or x are indefinite, until we find their numerical values, and the numerical values are nothing we can understand until we apply them to objects or processes. We shall therefore convert algebraical notions into the simpler system of mathematics—arithmetic, and thus analyse the initial mathematical ideas as taught through algebra.

10. Consider what the plus (+) and minus (—) signs mean? As we cannot destroy atoms, so we cannot create them. All therefore we can conceive by the

plus sign is that objects (that is, simple atoms, or aggregations of atoms) are moved from one position in space to another. That part of space which has gained is plus, the part which has lost is minus; hence, we obtain, as it were, a natural equation: $+1 = -1$. So also in dealing with the minus sign; from the plus we remove certain objects, and we say the greater is minus the less, and the result or equation is the remainder. We cannot take more objects from any part of space than exists, so that the minus sign must always be subordinate to the plus sign. A moment's thought shows that, *with objects,* arithmetic and algebra can do no more than the plus or the minus. We may amplify this process to almost any extent—hence, multiplication is a form of addition, and division is a form of subtraction. It is nothing more, and cannot be made more or less. But what says the mathematician? We must bear in mind that when we put down figures, unless otherwise expressed, they always mean plus (+). Thus 8 means "+ 8." This is the mathematical rule, and in order to make the mathematical notion quite clear we will put the numerical value of *the objects* in heavy letters thus **8**, and the *process or operation* in italics, thus *8*, and note the mathematical results. So then we have numerals representing two orders of thought, one objective, the other an order of action—operation, or motion of the object —work done. Division is inverse multiplication. Thus,

in multiplication, we say, $4 \times 4 = 16$. That is, four objects brought from one part of space to another four times, or four each time, equal 16 objects, and inversely in division we say 16 objects $\div$ *4* times equal 4 objects taken or subtracted at the time. We may formulate these concepts showing the direct and inverse processes in the following manner:—

MULTIPLICATION.					DIVISION.				
Multiplicand, or Number of Objects Operated upon.	Process, or Operation of Multiplication, Mathematically Symbolised.	The Multiplier, or Number of Times the Objects are Added.		The Result of the Operation—the Equation, *i.e.*, the Number of the Objects resulting from the Operation—the Product.	The Dividend, or Number of Objects Operated upon.	Process, or Operation of Division, Mathematically Symbolised.	The Divisor, or Number of Times the Objects are Subtracted.		The Result of the Operation—the Equation, *i.e.*, the Number of Objects Subtracted each Time—the Quotient.
+ 4	×	*4*	=	16	+ 16	÷	*4*	=	4
+ 4	×	*3*	=	12	+ 12	÷	*3*	=	4
+ 4	×	*2*	=	8	+ 8	÷	*2*	=	4
+ 4	×	*1*	=	4	+ 4	÷	*1*	=	4
+ 4	×	*0*	=	0	+ 0	÷	*0*	=	4

Now the last operation in multiplication is perfectly unthinkable, it cannot exist in fact, it is a mental process which is impossible, for to multiply + 4 nought times is to do nothing to the 4 objects, it is no process whatever and should not be mathematically expressed; but the absurdity of the concept becomes remarkable when we show the inverse process of division + 0 divided by *0*; which in this case gives a quotient of 4, *i.e.*, 4 objects. This result is, however, quite in harmony with mathematical

reasoning! It will be objected the last case of multiplication does not mean plus or + 4 (§ 11 foot-note). This cannot be so because the system implies that before a number the plus sign is always understood. We take a text-book of arithmetic, a work which has been reprinted twelve times, which states, "When 2 is multiplied by 3, the number "obtained is the sum of 2 repeated 3 times, which sum "$= 2 + 2 + 2 = 6$." Here the plus sign is omitted before the first 2, but it is understood to exist. Consider the following $(+ 2 + 2) \times \mathit{0} = 0$. The mathematical idea is unthinkable. We have here added 2 objects to 2 objects, making a sum of 4 objects; the process is complete, *the objects are brought over*, and then having brought them from one part of space to another, for this is all addition can mean when applied to objects, we multiply them *0* times, and then, says the mathematician, the 4 objects have disappeared! This is the notion of a mathematical power to annihilate matter. So also is the inverse process $0 \div \mathit{0} = 4$ involves the concept of the mathematical power to create matter.

The mathematician says that 4 objects multiplied *3* times, *i.e.*, $4 \times \mathit{3}$, is the same as 3 objects multiplied *4* times, *i.e.*, $3 \times \mathit{4}$. A moment's thought shows there is a real physical difference, a difference in the process and a difference in the number of objects operated on at the time. Hence $4 \times \mathit{0} = 4$ is not the same as $0 \times \mathit{4} = 0$. In the latter the operation is shown, but the objects do not exist.

11. Mathematical ideas become much more incomprehensible when we consider multiplication or division by fractions. Consider the following: $1 \times \frac{1}{2} = \frac{1}{2}$. That is to say, one object multiplied by $\frac{1}{2}$ operation equals half an object. What is meant by multiplying by $\frac{1}{2}$? We grasp mathematical ideas when we use the plus sign or the minus sign, *i.e.*, addition or subtraction, and we can mentally understand the sign of multiplication of objects when the multiplier is a whole number, and the sign of division when the divisor is a whole number, but the mind utterly fails when we attempt either process by a fraction. Let us think; what can be meant by bringing over an object by half an operation? does it mean half the distance? If so, try by experiment to bring over one object half a distance, and get a result of half an object. The idea cannot be grasped, nor can the inverse process $1 \div \frac{1}{2} = 2$ objects. Even the mathematical mind here fails. Consider the following confession from a well-known modern text-book on algebra:—*

"The definition of multiplication, in the strict sense "of the word, supposes that a quantity is to be added "to itself† a certain number of times. But when the

* "Elementary Algebra," by Hall & Knight. 5th edition, 1889, p. 133.

† Thus $+ 4 \times 0 = 0$, *i.e.*, + 4 objects "the quantity *added to itself*" 0 times, and the original 4 objects, to which nothing is added, disappear! Or we may put it thus: If multiplication is addition, we must elect one of these two as facts: $+ 4 + 0 = 4 = + 4 \times 0 = 4$, *or*, $+ 4 + 0 = 0 = + 4 \times 0 = 0$. This latter cannot be understood.

"multiplier is a fraction this definition ceases to be "intelligible; the operation can therefore be only under- "stood in some extended sense."

Now what is the extended sense? Simply substituting letters or symbols for numbers which have absolutely no sense or value whatever until the symbols are transferred into numbers. And, further, the numbers have no sense until they are made, in the case under consideration, to represent objects or operations.

12. Moreover, multiplication is confessed by the mathematician to be a form of addition, an amplification; to multiply by a fraction is a subtraction—a making less, hence it follows the mathematician's concept of addition is subtraction, which most certainly is a contradiction of terms.

13. Consider the following: 2 objects + 2 objects = 4 objects, or 4 objects − 2 objects = 2 objects. Here the plus or minus signs give definite ideas; but suppose we take an object and divide it into two parts, it may be two equal or unequal parts; it is, however, the minimum division, it cannot be divided into fewer parts, yet mathematics wholly fails in giving any sign showing this process. Thus in the first two cases we can write the objects, the process, and the result thus:—

$$2 + 2 = 4$$
$$4 - 2 = 2$$

while in the third case all we can write down mathematically is

$$1 \ast = \frac{2}{2}$$

The asterisk represents the position where the process or operation should be placed by some arithmetical sign; this, however, is wanting. Now dividing an object into two parts is as clearly a mathematical process as is adding or subtracting. How incomplete, then, is mathematical science!

14. Let us consider the algebraical formulæ relating to the minus sign when the value of the symbol is expressed in figures, which must always be done before we can approach definite ideas. The figures then represent objects and operations. Let us multiply – 100 (*i.e.*, minus 100 objects or units) by – *100* operations. The latter expression is unthinkable. But the mathematician says the result of the process, the product, is (plus) + 10,000 objects!

See if we can realize this idea. We will take two bowls and mark one A and the other B. In the bowl A are 100 marbles, *i.e.*, 100 objects. We take the 100 objects out of the Bowl A and put them in Bowl B. This is mathematically expressed: Bowl A — 100, Bowl B + 100. Now multiply the contents of Bowl A (– 100) by – *100* times, and then, says the Mathematician, there are 10,000 objects in that bowl! The test of all ideas is experiment. We can imagine anything; the test of the truth of our notions is expressed in the words, "Can the operation be performed?" Mr. Mathematician, take two bowls and 100 marbles and perform

the operation you express, and we then can believe in your fundamental ideas.

15. "The fundamental truths of the science of "Number all rest on the evidence of sense; they are "proved by showing to our eyes and our fingers that "any given number of objects, ten balls, for example, "may by separation and re-arrangement, exhibit to our "senses all the different sets of numbers the sum of "which is equal to ten. All the improved methods of "teaching Arithmetic to children proceed on a knowledge "of this fact. All who wish to carry the child's *mind* "along with them in learning Arithmetic, all who wish to "teach numbers and not mere ciphers, now teach it "through the evidence of the senses in the manner we "have described."*

Now, reader, can your *mind* understand that addition is subtraction; in other words, that 6 objects multiplied $\frac{1}{2}$ times become 3 objects ($6 \times \frac{1}{2} = 3$)?

16. Let us consider what is meant by "zero." Take a thermometer in the hand. It is marked in the centigrade scale. Here we have zero and the minus sign shown on the scale. Zero represents the temperature of melting ice; it is a measure of a ratio only. 100° represents the temperature of boiling water, again a ratio only. This registration or marking by degrees is

* "Mill's Logic," ch. vi., § 2. From Sonnenschein & Nesbitt's "A B C of Arithmetic," part II., p. 3.

purely arbitrary; it depends upon human choice only. Such arrangements are of great convenience to the human being, as they give ideas of differences, but differences only. We can have any number of such arrangements, and, indeed, three different orders of degrees are commonly in use. The boiling point of a Fahrenheit thermometer is 212°; of a Centigrade, 100°; of a Réaumur, 80°; while the freezing point of a Fahrenheit is 32°, that of a Centigrade and of a Réaumur is *zero* = 0°. These very facts show the artificial condition of things. These fixed points are very necessary for practical purposes for obtaining ratios and equations, but they give no idea of the processes in Nature. We can better understand what is going on in the thermometer tube without graduation than we can with, because the degrees tend to divert our thoughts from the real to the artificial.* Nature recognises no *zero* point as marked on the tube. What is required to be understood is not the ratio of the expanding of the mercury to boiling water, but, *what takes place in the tube when the mercury expands*? Graduation does not help us in this. It is here the reasoning of the metaphysician brings in the error, because he gets so saturated with the artificial that he attempts to substitute it for the real.

* *For this reason whenever practical, in this essay, the numerical ratios are omitted.*

17. We have now shown that arithmetic is at least, in part, an unreal, an unnatural, and purely artificial system of reasoning, and that the mathematician professes to do the impossible—that his concepts reduce our good sense to nonsense. This is certainly the fact when confining our figures to represent objects, and operations on those objects. In this essay we are going to deal with objects, viz., atoms and molecules. However useful the science of mathematics is, and always must be as a mental exercise and as a science for measurements for practical or commercial purposes, yet we venture to state it should never attempt the impossible by representing as facts that which cannot be. The mathematician should not lead; he should quietly follow. Our leader in the matter under consideration should be experiment, and experiment only. The mathematician, however, not only does attempt to lead, but, as we shall see, lays down certain fundamental metaphysical ideas as facts, and without proving them (§ 40).

The following remarkable piece of evidence from a great mathematician is worth careful thought:—

"Mathematicians may flatter themselves that they "possess new ideas which mere human language is as "yet unable to express. Let them make the effort to "express these ideas in appropriate words without the "aid of symbols, and if they succeed they will not only "lay us laymen under a lasting obligation, but, we "venture to say, they will find themselves very much "enlightened during the process, and will even be

"doubtful whether the ideas, as expressed in symbols, "had ever quite found their way out of the equations "into their minds." *

18. Having dealt with the fundamental principles of algebra and arithmetic, let us approach geometrical fundamental notions and we shall see what great difficulties are created by the mathematician. He commences by giving definitions which, although useful in a sense, are inconceivable, impossible. Consider a point without dimensions, the mind fails; or consider a line without breadth, and again the mind fails. Make the very finest point upon a piece of paper, say with a pencil. We know by experience the pencil has lost something; the paper has gained something. Look at that which the paper has gained under the microscope, and see what a mass of matter (every molecule of which has dimensions) has been transferred to the paper, and this is the nearest concept we can obtain, and we are told this point is without dimensions!

"The foundation of all sciences, even deductive or "demonstrative sciences," says Mill, † "is Induction;

* "A Review," by James Clerk Maxwell. (*Nature*, vol. vii.). "From the Scientific Papers of James Clerk Maxwell," vol. ii., p. 328 (1890). It is curious to note that when Maxwell, the eminent mathematician, wrote this review he did so as a "layman." It is a sad confession for one who belonged to a department of science which claims to be perfect, infallible, and absolutely comprehensive. (*See* also § 28.)

† "A System of Logic" (8th edition), p. 168 *seq.*, from "Stallo's "Concepts and Theories of Modern Physics," 1885, p. 217.

"every step in the ratiocination of geometry is an act "of induction. . . . The character of necessity ascribed "to the truths of mathematics, and even (with some "reservations to be hereafter made) the peculiar cer- "tainty attributed to them is an illusion; in order to "sustain which it is necessary to suppose that those truths "relate to, and express, the properties of purely imaginary "objects. It is acknowledged that the conclusions of "geometry are deduced, partly at least, from the so-called "Definitions, and that those definitions are assumed to "be correct representations, as far as they go, of the "objects with which geometry is conversant. Now, we "have pointed out that, from a definition as such, no "proposition, unless it be one concerning the meaning of a "word, can ever follow; and that what apparently follows "from a definition follows in reality from an implied "assumption that there exists a real thing conformable "thereto. This assumption, in the case of the definitions of "geometry, is not strictly true; there exist no real things "exactly conformable to the definitions. There exist no "points without magnitude; no lines without breadth, nor "perfectly straight; no circles with all their radii exactly "equal, nor squares with all their angles perfectly right. "It will perhaps be said that the assumption does not "extend to the actual, but only to the possible, existence "of such things. I answer that, according to any test we "have of possibility, they are not even possible. Their "existence, so far as we can form any judgment, would "seem to be inconsistent with the physical constitution of "our planet at least, if not of the universe. To get rid "of this difficulty, and at the same time to save the "credit of the supposed system of necessary truth, it is

"customary to say that the points, lines, circles, and "squares which are the subject of geometry exist in our "conceptions merely, and are part of our minds; which "minds, by working on their own materials, construct an "*a priori* science, the evidence of which is purely mental, "and has nothing whatever to do with outward experience. "By however high authorities this doctrine may have "been sanctioned, it appears to me psychologically in-"correct. The points, lines, circles, and squares which "anyone has in his mind are (I apprehend) simply copies "of the points, lines, circles, and squares which he has "known in his experience. Our idea of a point I "apprehend to be simply our idea of the *minimum visible*, "the smallest portion of surface which we can see. A "line, as defined by geometers, is wholly inconceivable. "We can reason about a line as if it had no breadth; "because we have a power, when a perception is "present to our senses, or a conception to our in-"tellects, of *attending* to a part only of that perception "or conception, instead of the whole. But we cannot "*conceive* a line without breadth; we can form no mental "picture of such a line; all the lines which we have "in our minds are lines possessing breadth. If any-"one doubts this, we may refer him to his own ex-"perience. I much question if any one, who fancies "that he can conceive what is called a mathematical "line, thinks so from the evidence of his consciousness. "I suspect it is rather because he supposes that, unless "such a conception were possible, mathematics could "not exist as a science: a supposition which there "will be no difficulty in showing to be entirely "groundless."

Now, reader, look at the space below. On it are points, lines, circles, and squares according to the definition of the geometrician !

19. Even the way geometry and algebra get mixed is worthy of remark. "The practice," says Stallo, "of reading "x^2 and x^3 as x square x cube, instead of x of the second " or third power, is founded upon the silent or expressed " assumption that an algebraic quantity has an inherent " geometric import."* " Now, number is discontinuous. We " pass from one number to the next *per saltum*. The magni- " tudes, on the other hand, which we meet with in geometry, " are essentially continuous." † But algebra deals only " with " the relations and properties of numbers by means of " letters and other symbols " (§ 9). Hence we obtain in the above illustration mathematical confusion.

* " The Concepts and Theories of Modern Physics," by J. B. Stallo, second edition, 1885, p. 269. The absurdity of this error is very evident in clause 23.

† J. Clerk Maxwell. From " Encyclopædia Britannica " (Copied from " The Scientific Papers of J. C. Maxwell," p. 446, " On Atoms ").

20. Mathematicians see these difficulties. It is but natural, in process of the education of the human being, this should be so. The age of mathematics as a science, dates practically, before any other science. All other sciences have progressed, and the science of mathematics must progress also, to be made conformable, and rigidly conformable, to the present known facts, and to those facts only. We cannot conceive a line multiplied by a line. We might as well say we can multiply an apple by an orange. Sonnenschein and Nesbitt, in their "A B C of Arithmetic," appear to have made a successful and intelligent step to remove such initial fallacies in mathematics. Instead of multiplying a line by a line, they give real objective ideas of cubes ranged in staves, and thus we get a concept of ten staves of ten cubes each making 100 cubes. This is the concept of 10 objects, taken *ten times* to equal 100 objects, and this is quite intelligible, and very different from the notion of multiplying a line by a line. If mathematicians will progress with ideas, such as are thus coming to the front, much—very much—confusion will pass away.

21. Consider 1 foot multiplied by half a foot. The mathematician puts it $1 \times \frac{1}{2} = \frac{1}{2}$. The process is illogical and really unthinkable. What is the product $\frac{1}{2}$? The figures cease to be of the same quality as the original factors. The fraction has found a new value; it is not half of the original unit, but of an area—a square foot—but it is not so expressed, and thus by a process of chopping and changing by "understood" and not "expressed" conditions only, is the equation intelligible. It really should stand thus:

12 square areas multiplied *6* times = 72 areas; or, by a theory of substitution, we may suppose 1 = 144, then $1 \times \frac{1}{2} = \frac{1}{2} = \frac{144}{2} = 72$, which is the answer in areas—square inches. To say 1 = 144 is obviously unreasonable, for it may equal any other number! This is not *exact*, but *inexact* reasoning—it is a contradiction of terms.

22. To thoroughly appreciate the metaphysical notions of the mathematician, and how completely unreal his ideas are, let us consider those valuable lines—the imaginary lines of the earth: latitude and longitude. No one questions their importance, but are they real? Most certainly not, nor will the mathematician attempt to say they are real. So far from the existence of their reality, we find nations select different longitudes, which could not be the case if longitudes were existing in Nature. How necessary it is, then, in investigating the real facts of Nature, that we should avoid stultifying our position by attempting to tie ourselves to the rigid concepts, useful as they are, of the mathematician.

23. Perhaps we can best illustrate the argument by the following pertinent example. Everyone knows that matter expands when it is said to be heated, the only exception being when there is a change of state in the molecule, such as during the process of crystallization (§ 180). Now this increase in dimension is called by the physicist the co-efficient of expansion. We will give two illustrations of this expansion from two well-known text-books.

Fig. 1 is from "Garnett's Elementary Treatise on Heat"; Fig. 2 from "Deschanel's Natural Philosophy," Part II.—Heat. The first thing which immediately strikes the thinking reader is, that there are here figured two expressions of one fact, quite different—both cannot be right.

In the first case the idea is that when a body of a certain temperature, *i.e.*, a certain volume, expands,

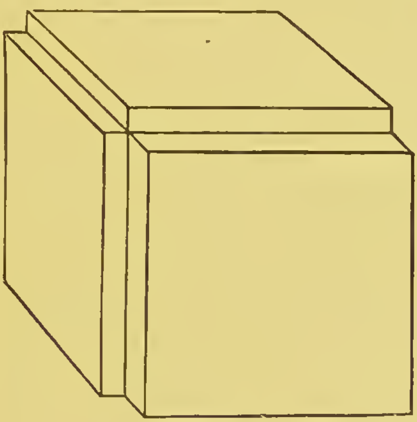

Fig. 1.

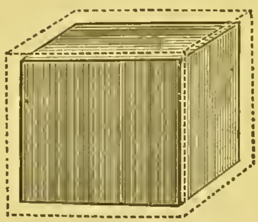

Fig. 2.

Nature picks up a volume of matter—slabs as it were, of matter—three pieces, and places them on three sides of a cube. Then, in order to make the increased volume a larger cube, the mathematician supposes that Nature puts into the vacant edges three long rectangular pieces to fill up those spaces; and then, to complete, he supposes that Nature adds a small cube to the corner. This is a pure geometrical concept, but what a monstrosity the idea is! We will describe the process in the words of the physicist:

"Most substances, except crystals, expand equally in all "directions when heated. Imagine a cubic block, the length "of whose edge is 1 foot: its volume will then be "1 cubic foot. Now suppose that on raising its tempera-"ture 1° C., the length of its edge becomes $1 + a$ feet, "so a is its co-efficient of linear expansion.* Then its "volume is $1 + 3a + 3a^2 + a^3$ cubic feet,† and "the increment of its volume is $3a + 3a^2 + a^3$ "cubic feet. The ratio of this to the original volume, "viz., one cubic foot, is $3a + 3a^2 + a^3$, which ex-"pression is therefore the co-efficient of cubic expansion. "Now a is, in general, very small; hence a^2 and (a "*fortiori*) a^3 may be neglected in comparison with a. We "have then for the co-efficient of cubic expansion $3a$ "or *the co-efficient of cubic expansion is three times the co-"efficient of linear expansion* for the same substance. . . . "The effect of neglecting the terms involving a^2 and a^3 "may be illustrated by taking a cube of 10 centimetres "side, three plates each 10 centimetres square and 1 "centimetre thick, three strips each 10 centimetres long "and 1 centimetre square, and a cubic centimetre. Placed "together, these will build up a cube of 11 centimetres "edge. If we neglect the three strips and the cubic "centimetre, our enlarged cube is incomplete at the edges" (Fig. 1), "and this is equivalent to neglecting $3a^2$ and "a^3 in the above expression."

"Or we may employ the following illustration. Take a "cube of wood or other material of one foot edge, and let

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* It should be here remarked, "linear expansion" is purely a metaphysical concept, because no matter can have length without breadth and depth. In Nature, matter acquires cubical expansion when it is heated; but it is not the expansion described above, by the geometrician.

† See clause 19.

"this represent the unit of volume. Suppose a to be ·01. "Then a piece of pasteboard of one foot square and ·01 ft. "thick will contain a units of volume, while its thickness "will be a units of length. Take three such plates, the "sum of whose volumes is $3a$,* and apply them to the three "faces of the cube which meet in a point. Now take three "rectangular strips of pasteboard a foot long and ·01 ft. "square. The volume of each of these is a^2,† and the "volume of the three together is $3a^2$. If these strips be "laid in the grooves formed by the edges of the plates, "there will only be required a cube of ·01 ft. side and volume "a^3 in order to complete a cube of 1·01, or $1 + a$ feet edge. "The whole increment in volume of the one foot cube is "the volume of the three plates together with that of the "three strips and the small cube, or $3a + 3a^2 + a^3$. "If we take the co-efficient of cubic expansion to be "three times that of linear expansion,—that is, take "into account the plates only,—we neglect the strips "and the little cube; but even when the linear expan- "sion is so great as ·01 of the original length, the "error so introduced is very little more than 1 per "cent." ‡

Now Deschanel, seeing no doubt the geometrical error as illustrated in Fig. 1, substitutes Fig. 2, the dotted lines of which really represents the true co-efficient

* It will be noticed here $3a$ is a linear expansion, $3a^2$ is a surface expression, while in the illustration both are objects of cubical dimensions.

† The *volume* of an object described as of superficial area only is a contradiction of terms.

‡ "Elementary Treatise on Heat," by William Garnett, M.A. (5th edition), 1889, p. 66.

of expansion; but here comes the difficulty, and this is very important to observe—the notion of the mathematician is to try to force natural phenomena to follow rigid lines, and Nature abhors it—in fact, will not have such an idea. It would seem, the mathematical mind cannot express the co-efficient of expansion as Nature performs the act, *for Deschanel is driven to the same formula as Garnett gives to explain his diagram!* He substitutes only the letter l for the letter a. Thus he expresses the reaction of the addition of Heat to the solid in these words:

"If a cube, whose edge is the unit length, expands "equally in all directions, the length of each edge will "become $1 + l$, where l is the linear expansion; and "the volume of the cube will become $(1 + l)^3$ or "$1 + 3l + 3l^2 + l^3$. In the case of thermal expansion "of solid bodies l is always very small, so that l^2 and l^3 "can be neglected,* and the expansion of volume is "therefore $3l$; that is to say, the *cubical expansion is three* "*times the linear expansion.* This is illustrated geometrically "by" Fig. 2, "which represents a unit cube with a plate "of thickness l, and therefore of volume l applied to "each of three faces; the total volume added being "therefore $3l$." †

* How incomplete or crude is this mathematical notion! Nature does not deal with "neglected" factors. Nature is exact and perfect in the increment of expansion. The fact is, the co-efficient of cubical expansion, as explained by the geometrician, is absolutely unnatural.

† "Elementary Treatise on Natural Philosophy." Part II. Heat, by A. P. Deschanel. Edited by J. D. Everett, M.A., etc. (11th edition), 1889, p. 277.

Now notice the error of expression, the Fig. 2 does "not represent the increase of volume by "three faces," but by six faces!

Thus the idea given by the mathematician, in the case of expansion of matter by increase of temperature, is the *addition* of matter to matter. This, in the sense in which it is used, every one knows, is not true.

24. Again, let us take the broad notion thus expressed by the physicist and see how utterly unnatural it is. Railway engineers, in order to allow for expansion by increase of temperature, place the rails a short distance asunder. Now, the concept expressed above by the physicist is, that in the hot weather Nature picks up some steel, places a piece on one end of the rail and a strip on one side and a strip on top. With such an idea we should see, in cold weather, pieces of steel lying beside the rails as a sort of great-coat of *always variable thicknesses*, which the rails have cast off because the weather is cold, and ready to put on when the weather is hot. Is it possible to have a clearer illustration of the unreasonableness of mathematical concepts? True, such ideas have value for utilitarian or commercial purposes, but they are absolutely unreal and should be regarded as such. Can we wonder, therefore, that the physicist, approaching Nature with such fundamental notions, fails to penetrate the truths of Nature.

25. The science of mathematics stands pretty nearly to the truth as a picture does to reality. Imagine a beautiful painting—a landscape. Every part perfectly finished and in just proportions, save one defect—the artist has chosen to paint a house standing in mid-air. The picture immediately becomes an absurdity; but it is quite possible to so represent a copy of Nature. In like manner does the mathematician express the impossible; only there is this difference: in the former case, the absurdity is immediately apparent, while in the latter it requires a patient study to detect the mental monstrosity.

Or we may say mathematics is a science which stands in the same relation to facts as the work of the architect—his plans and elevations—does to the edifice built or to be built. So long as his paper work is in harmony with facts and the possible, just in that proportion is his work valuable, but it is easy to make such drawings utterly absurd. The numbers of the arithmetician, the letters of the algebraist, and the figures of the geometrician are practically mental and expressed ideas, which stand in the same relation to facts as the drawings of the architect, and subject exactly to the same errors.

26. Painting is a language of its own, but it is as easy to paint the absurd as to copy the real, so in like manner mathematics is a language of its own, and by this language good sense and nonsense can be

expressed the same as any other language can. But to suppose that the mathematician is master of the situation because he understands his language is to suppose that he who has learnt a language is only capable of speaking wisdom.

27. Unfortunately in our system of education, and in the division of labour, the physicist is compelled to trammel his mind with the rigid and fixed ideas of the metaphysician*—the mathematician. He is not permitted to take his position in his profession unless his mind is fixed by this rigid education. How is it that the geometrician avoids the greater forms in Nature? Take a tree, an animal, an insect;

* The author, in order to fully grasp the great questions under consideration, attended the classes of one of our leading educational institutions in London. After one of the examinations, the Professor (an eminent authority) addressed the pupils, somewhat in these terms: "It is a curious fact that just as your mathematical education im-"proves your common sense seems to leave you; many of the papers "are so absurd in their replies, that an ordinary uneducated person "could give much better answers. For instance, if I were to ask a "person not educated in mathematics to give me the cubical capacity "of this room, he would very roughly give me, more or less, an "approximately correct reply; but your answers are equivalent to giving "a cubical capacity of so many cubic miles." The young men, the author found, were being educated as mere calculating machines; they were to a great extent devoid of reasoning power. This is the result of mathematics! A young friend of the author's, at ——— College, Cambridge, who was excelling in mathematics, told him that just as his education was improved in mathematics, his power to think on most ordinary subjects seemed to be leaving him!

take almost any natural object, except the crystal, and where is his geometrical formula for any one of the objects? Go, Mr. Physicist, and look at that small but ever-changing and wonderful object, the amœba, and having studied it, ask yourself: What is the value of geometry with its rigid ideas for the objects Nature makes? and then, when you have sufficiently considered how limited your powers are, cease to hold that overbearing position you too often assume. Great are the utilitarian or practical results obtained by your method, but it gives no idea of the processes in Nature. Your method is a craft, and no doubt one object you have is to keep your knowledge as select as possible. It should not, however, be so. The physicist should hold the keystone of knowledge. Knowledge is for all, and not for a select few. It is by universal or nearly universal knowledge, only, we can avert a crisis to which civilization seems approaching.* Let us, therefore, suppress any attempt to stop the progress of that which is of so much universal good.

To sum up, our contention is: Except addition and subtraction of objects (such as is recognised by the chemist and physicist in the atomic theory, which is a rigid process), Nature probably recognises no other rigid process. And that a mind educated on rigid lines, as the physicist is, from the necessities of the case, is the least capable of solv-

* This issue is clearly seen when biological evidence is considered in relation to human actions.

ing a problem which, we think, can only be solved by views which are foreign to the fundamental ideas in which the physicist has been educated.

28. The effort of the physicist to complicate phenomena can be well illustrated by the following passage from Clerk Maxwell's "Theory of Heat," edition 1891, p. 197:

"In this way we may trace out on the model two "series of lines: lines of equal pressure, which Professor "Gibbs called Isopiestics; and lines of equal temperature, "or Isothermals. Besides these, we may trace the three "systems of plane sections parallel to the coordinate "planes, the isometrics or lines of equal volume, the "isentropics, or lines of equal entropy, which we formerly "called, after Rankine, adiabatics, and the isenergics, "or lines of equal energy"!

And so the physicist goes on floundering in these outlandish terms, always representing equations and ratios of something he does not understand until at last he collapses, for at page 205 he finds himself in a system involving "the *spinode* curve," the "node couple," the "*tacnodal* point," and other geometrical terms beyond even Professor Clerk Maxwell, for in a foot-note he is obliged to confess, "For these geometrical "names I am indebted to Professor Cayley." We may add this advice to the physicist;—Well done, Mr. Physicist! When you do not understand a thing, give a complex name to that which you do not under-stand. (§ 17.) It looks so learned, and the ignorant

admire it so very much. But, does knowledge increase by such means?

"It lies in the nature of philosophy that it should "be common property. Expositions which are not in- "telligible to an educated man, are scarcely worth the "ink they are printed with. Whatever is clearly con- "ceived can be clearly expressed. The philosophical "mists which envelope the writings of scholars, appear "intended more to conceal than to exhibit their thoughts. "The times of scholastic bombast, of philosophical "charlatanism, or, as Cotta says, of intellectual jugglery, "are passing away. May our . . . philosophy soon "perceive that words are not facts, and that, to be "understood, we must use intelligible language." (Dr. Louis Büchner.)

29. Yet how the physicist instinctively deplores his position! How clearly he feels something is wrong! How thoroughly he feels his utter incapacity to get out of the rut the metaphysician has forced him into! And how perfectly he is beyond his depth! No words can better show the position than the following remarkable confessions of Professor Lodge:—

"I am also convinced that it is unwise to drift "along among a host of complicated phenomena with- "out guide other than that afforded by hard and rigid "mathematical equations. The mathematical theory of "potential and the like has insured safe and certain "progress, and enables mathematicians to dispense for "the time being with theories of electricity and with "mental imagery. Few, however, are the minds strong "enough thus to dispense with all but the most formal

"and severe of mental aids; and none, I believe, to "whom some mental picture of the actual processes "would not be a help if it were safely available."*

"The human mind," says Clerk Maxwell, "is sel-"dom satisfied, and is certainly never exercising its "highest functions when it is doing the work of a "calculating machine."†

30. All the physicist's terms are terms of ratios and equations of something he does not comprehend. He does not know what he is talking about when he speaks of his terms. His temperature, his co-efficient of expansion, his volts, his ohms, his ampères, &c., are all terms which he does not understand; he only knows they convey certain ratios to each other. Thus, speaking of electrical radiation, Professor Lodge states:—

"The other thing on which the speed of radiation "waves depends is the medium's density — its electric "density, if so it must be distinguished. Here, again, we "do not know its absolute value. Its relative or apparent "amount inside different substances is measured by mag-"netic experiments, and called their specific magnetic "capacity, or permeability, and is denoted by μ. Being "unknown, another convention has arisen, quite incom-"patible with the other convention just mentioned, that "its value in air shall be called I. This convention is "the basis of the artificial electro-magnetic system of units "—volts, ohms, ampères, farads, and the like. Both of

* "Modern Views of Electricity," 1892, p. 67.

† "The Scientific Papers of James Clerk Maxwell." Cambridge University Press, 1890. Vol. 2, p. 219.

"these conventions cannot be true; no one has the "least right to suppose either true."*

31. Heat and electricity are so closely allied that they are probably different manifestations of the same. If this is the case, then the plain confessions of Dr. Lodge bear not only on ratios relating to electricity, but also on Heat; indeed, they bear upon the whole of physical science, as it is almost wholly built up upon mathematical concepts.

32. How true are the statements made by Stallo:

It is a "well-known fact that exclusive devotion to the "labors of the mathematical analyst has a tendency to "develop certain special powers of the intellect at the ex-"pense of its general grasp and strength" † . . . "The "blindness of eminent physicists to some of the most "obvious consequences of their own theories is mar-"vellous." ‡

The formulæ of the physicist "are in many cases "simply results of a series of transformations of an equa-"tion which embodies an hypothesis whose elements are "neither more nor less than the elements of the pheno-"menon to be accounted for, the sole merit of the "emerging formula being that it is not in conflict with "the initial one." "All hypotheses are futile which "merely substitute an assumption for a fact, and thus,

* "Modern Views of Electricity," 1892, p. 261.

† "The Concepts and Theories of Modern Physics," by J. B. Stallo. 2nd edition, 1885, p. 249.

‡ *Idem*, p. xxxiii.

"in the language of the schoolmen, explain *obscurum per* "*obscurius*, or (the assumption being simply the statement "of the fact itself in another form—the 'fact over again') "illustrate *idem per idem.* And the futility of such hypo- "theses goes to the verge of mischievous puerility when "they replace a single fact by a number of arbitrary "assumptions, among which is the fact itself."*

33. This chapter cannot be closed with better words than those chosen by Stallo in that very valuable work, "The Concepts and Theories of Modern Physics" (p. 107), for we fully endorse the views expressed:

"I hope not to be misunderstood as disparaging the "services for which physical science is indebted to mathe- "matics. These services—especially those rendered by "modern analysis—are incalculable. But there are mathe- "maticians who imagine that they have compassed a "solution of all the mysteries involved in a case of "physical action when they have reduced it to the form "of a differential expression preceded by a group of "integral signs. Even when their equations are integrable, "they should bear in mind that the operations of mathe- "matics are essentially deductive, and, while they may "extend, can never deepen a physical theory."

34. We might proceed much further in this strain, but it is not our object to write a book on this question; we only wish to give sufficient evidence to show that mathematics can do but little to effect the object we have in view, and to shift the solving of the great

* "The Concepts and Theories of Modern Physics," by J. B. Stallo. 2nd edition, 1885, p. 107.

problems, we shall attempt to solve, from off the shoulders of the mathematician. Those who take interest in these questions should carefully read the work so often quoted —"Concepts of Modern Physics," by J. B. Stallo (The International Scientific Series).

35. As we shall have to deal with the motions of atoms and molecules, and with their inherent properties, we shall therefore omit any reference, if possible, to mathematical formulæ. This is the more desirable because Clerk Maxwell candidly acknowledges:—

"The mathematical difficulties arising in the investi-
"gation of the motions of molecules are so great that
"it is not to be wondered at that most of the numeri-
"cal results are confined to the phenomena of gases." *

And he should have added the reactions, considered in the light of the mechanical or dynamical theory, as applied to gases, are absolutely contradictory, and this we shall presently see.

36. As we can obtain, therefore, no real help from the metaphysician or mathematician, we proceed by other methods. We shall endeavour to give a graphic picture of the atoms and molecules, their physical constitution, their motions, and their general reactions. We shall propound an hypothesis and shall assume that it is true, not that we wish to approach these great

* "Theory of Heat," by J. Clerk Maxwell. 10th edition, 1891, p. 333.

fundamental questions in a dogmatic style—this is farthest from our thoughts, but we have a very difficult task, and we have to bring the issues before the reader in the very clearest manner. This, we think, is best done in the way a barrister pleads his case in defence of his client, and, like him, we shall assume our case is pure—that it is the truth—we shall so state it, and we shall bring powerful evidence to prove that it is so, because we believe it is the whole truth, and nothing but the truth, and we shall place the onus upon our opponents to prove our case false. Although we shall for the sake of debate assume this position, we add it *is an assumption only, and the most we can say is: we hope we have stated the truth.* We believe this: If we have not succeeded in stating the truth, we have done something to advance it, and this will be a gain.

37. How do we know what is truth? There can be only one answer. Those concepts to which all Nature responds are true. Nature is not chaos, Nature is cosmos. What perplexes us is: Nature is so complex that we have heretofore failed in grasping the whole of the factors. We, however, are of opinion that the human race is progressive; and a time must come, and we think has come, when, in consequence of the recent marvellous mental development, the factors are within our reach.

38. Thus we can at this moment consider the negative or what is error, and it is impossible to state the

case in more telling words than those adopted by Stallo. He says:

"Now, when two hypotheses are radically inconsis-"tent with each other, one or both of them must even-"tually be discarded. It is true that in certain cases "hypotheses which have proved to be untenable, may "continue to be serviceable as 'working hypotheses,' in "a secondary sense, as mere devices for holding together "facts which have been collected by means of or with "reference to them. So long as they are employed for "this purpose alone, and with the clear understanding "that they are not propounded for any other, there can "be no serious objection to their use. But it is otherwise "when the specialist seeks to obtrude his own particular "hypothetical figment as a finality upon science generally, "and to make it the basis of assertions respecting the "ultimate constitution of things, and the universal order "of nature. It must not be forgotten that the several "departments of science are simply arbitrary divisions of "science at large, and that their extent and limits are "representative of nothing more than the necessities and "conveniences of the division of labor. In these several "departments the same physical object may be considered "under different aspects. The physicist may study its "molecular relations, while the chemist determines its "atomic constitution. But when they both deal with the "same element or agent, it cannot have one set of pro-"perties in physics, and another set contradictory of them "in chemistry. If the physicist and chemist alike assume "the existence of ultimate atoms absolutely invariable in "bulk and weight, the atom can not be a cube or oblate "spheroid for physical, and a sphere for chemical "purposes. And a group of constant atoms cannot be

"an aggregate of extended and absolutely inert and im-"penetrable masses in a crucible or retort, and a system "of mere centres of force as part of a magnet or of a "Clamond battery. The universal æther can not be soft "and mobile to please the chemist, and rigid-elastic to "satisfy the physicist; it cannot be continuous at the "command of Sir William Thomson, and discontinuous "on the suggestion of Cauchy or Fresnel." *

And states Clerk Maxwell :—

"If we are ever to discover the laws of Nature, "we must do so by obtaining the most accurate acquain-"tance with the facts of Nature, and not by dressing "up in philosophical language the loose opinions of men "who had no knowledge of the facts which throw light "on these laws. And as for those who introduce "ætherial, or other media, to account for these actions, "without any direct evidence of the existence of such "media, or any clear understanding of how the media "do their work, and who fill all space three or four "times over with æthers of different sorts, why the "less these men talk about their philosophical scruples "about admitting action at a distance the better." †

39. To sum up. One of the unavoidable faults of the age is: we have overdone division of labour. Each department starts for its own independent centre of thought. In a progressive condition of things, a time must be reached when these various centres must be

* "Concepts of Modern Physics," by J. B. Stallo. 2nd edition, 1885, p. xi.

† "The Scientific Papers of James Clerk Maxwell," vol. ii., 1890, p. 315. From "The Proceedings of the Royal Institution of Great Britain," vol. vii.

made to harmonise. We think, that time is now arriving, and that the necessities of things will enforce such harmony. There is always a great tendency for each department to struggle for its own existence. Men do not want the truth, they only want the support and existence of the special craft by which they live, and it is curious to observe the utter indifference men have to the mischief the existence of such departmental influence may have on the community. The cry of the crafts is now as of old, "Great is Diana of "the Ephesians." "Not only this our craft is in danger "to be set at nought, but also that the temple of the "great goddess Diana should be despised." We are now, however, living in a new order of things, and it is absolutely necessary that the pruning knife be used, and the rotten and pernicious cut out. It is not a choice, it is a necessity of the times or a reversion to chaos.*

40. It will be asked: Why this tirade against the phvsicist and his mathematical notions? Because *the* concept of the physicist, derived from his rigid mathemati-

* The causes of, probably, the great mass of human suffering are well known to physicians and doctors, and yet these departments in the division of labour are silent as to these causes. Why is this? Is it not because ignorance in the community brings trade to the professions? Here the division of labour is absolutely pernicious to the community, yet from the force of circumstances, from the departmental education received, only can these professions appreciate the gravity of these causes.

cal reasoning, is, that which he regards as the ultimate object—the true unit—the atom, or, as he calls it, the molecule, is an object of *fixed volume, shape or dimensions*. It is truly a mathematical notion. Every physicist, every book on physics, is saturated with this *one notion* —it is the *only* fundamental idea. Is it true? The object of this essay is to test this question. It was, therefore, necessary to put the physicist in the wrong as to his fundamental ideas, and this is the sole reason of this chapter. We think that the whole of the evidence is against this fixed, rigid view so persistently held by the physicist. We shall proceed to prove an alternative concept. If Nature supports this new view, we consider it right to believe *it is truth*.

PART II.

ON THE KINETIC THEORY.

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THE KINETIC THEORY.

41. All matter is built up of minute objects called "Atoms." These objects are so minute, the human eye has never seen one of them, but whenever we see matter we see a mass of these objects. This is the basis of the so-called "atomic theory." Well, what is a theory? Most people would say a theory is a "speculation, a doctrine, scheme, or system existing only in the mind." If, reader, one were to say to you, while you are reading this book, "It is a theory I have, that you are "reading this book at the moment that the book is before "you—that the book is a real thing, and that you are "a real being reading the book," you would look at such a person with a curious eye. You would naturally say to call such a fact "a theory" is—must be, very absurd. We would all agree with you. Is it not equally as absurd to call the existence of the atom and molecule "a theory"? The facts are as patent in the one case as in the other. Let us consider, we can apply the reaction called Heat to any and everything and by this means we can resolve matter, however complex the

matter may be, into certain free and independent objects, liquids, or gases, and we call the mass of those objects groups of atoms or molecules. Look at a little sphere of mercury, it is a group of molecules. We can mechanically divide the sphere until one of the masses becomes so small that we fail to further divide it; but that mass, minute as it is, is a group of objects, and thus we can mentally conceive that at last we arrive at a point when it is impossible to further, by any means, divide the mass—we then come to the ultimate particle —the molecule of mercury.* The healthy mind can conceive no other result; for if matter be divided to infinity, we divide matter into space. But the metaphysical mind or mind warped by an education built up from definitions, which are unthinkable and not real, can think otherwise, the same as such can conceive that matter is not, space is not, all are illusions of a brain which does not exist.

42. The "Atomic theory" is so well described in the article under that name in "Chambers' Encyclopædia" (new edition, 1888) that we copy the important parts, as follows:—

"What is known as the atomic theory is a theory "as to the nature of the ultimate particles of matter,

* The chemist believes that the element mercury exists in the condition illustrated, as a molecule—that is, each individual mercury entity consists of groups of atoms of mercury "bonded" together.

"which, supported as it is by both chemical and physical "evidence, has been of great service in the explanation "of chemical facts, as well as in the progress of scien-"tific chemistry.

"Theoretical speculations as to the nature of the "constitution of matter date from the earliest times of "philosophy, but the gradual development of the atomic "theory into its present form is owing to the accumu-"lation of chemical and physical facts during a period "of about a century. Matter has long been regarded "as not being continuous, but as possessing a *grained* "structure—*i.e.*, as being made up of extremely minute "particles. These particles, or groups of such particles, "are supposed to be arranged in any substance at a "certain average distance from one another,* such aver-"age distance depending not only upon the physical "state of the substance—*i.e.*, whether solid, liquid, or "gas—but also upon the temperature and pressure.

"The honour of having first formulated an atomic "theory based upon experimental evidence, obtained "from his own investigations, and from those of his pre-"decessors and contemporaries, falls to Dalton. Prior to "Dalton's first publication, at the beginning of this "century, of his contributions to the subject, a good "deal of investigation had been made leading up to the "establishment of a rational atomic theory, although it "had not been fully recognised as such at the time. It "was known that chemical compounds contained their "elements in certain definite and fixed proportions. More-"over, by finding the quantities of various acids required to "neutralise a given quantity of a particular base, and of

* Here comes in the first issue, which will be considered further on.

"various bases required to neutralise a given quantity of a "particular acid, it had been ascertained that numbers "could be assigned to each acid and base which repre- "sented quantities which were chemically equivalent. "Thus a quantity of an acid, A, combined with a quantity "of a base, B, to form a neutral salt, A B; the same quan- "tity of A combined with a quantity of another base, C, to "form a neutral salt, A C; and the same quantity of B "combined with another acid, D, to form a neutral "salt, D B. The important point which had been estab- "lished was, that the quantity of acid D in D B, and that "of the base C in A C, combined to form another "neutral salt, D C. It was also known that the quantities "of various metals dissolved by the same weight of "an acid were capable of uniting with the same "weights of oxygen. Further, it was known that "several metals and other elements formed more "than one compound with oxygen, the proportion of "the latter being different in each. Dalton showed that "when elements united with each other in two different "proportions, these proportions were related to each other in "a very simple way. Thus, he showed that a given weight "of carbon united with a certain proportion of oxygen to "form carbonic oxide, and with just twice as much to form "carbonic acid; also that in olefiant gas and in marsh-gas "the relation of the proportion of hydrogen for a given "weight of carbon was as one is to two. Other examples were "also known to him, notably in the case of compounds of "oxygen and nitrogen, which showed similar simple rela- "tions. This discovery of Dalton's was what has been "subsequently known as the *law of multiple proportions*, "and, to explain it, Dalton reverted to the atomic "hypothesis, which assumed that matter consists of atoms "of different weights, those of the same element being all of

"the same weight.* . . . Although Dalton's atomic "weights were far from accurate, yet his theory was sound "that the observed law of multiple proportions could be "satisfactorily explained by the atomic hypothesis. . . . "Other considerations have led in some cases to the fixing "of a certain atomic weight for an element, but with the "exception of what is known as Avogadro's law, these "need not be particularised here. Avogadro's law is of "the first importance, although its bearing was not recog-"nised until many years after its promulgation. . . . "Avogadro distinguished between elementary atoms, or the "smallest indivisible particles of an element, and molecules, "or the smallest portions of a substance, possessing all the "properties of the substance. His molecules are hence "groups of 2 or more atoms, each group being capable of a "separate existence. Avogadro's law is based upon some "considerations of the physical properties of gases, which "he held received their simplest explanation by the "assumption that a given volume of any gas, whether "elementary or compound, contains the same number of "molecules as the same volume of any other gas when "measured at the same pressure and temperature. . . . "If now Avogadro's law be true, the relative densities of "gases must represent their relative molecular weights "whether the gases be elementary or compound. Hence "we are led to suppose that the molecules of some elemen-"tary gases, as of compound gases, consist of 2 or more "atoms. Thus 2 volumes of hydrogen unite with 1 of

* It is absolutely impossible to place too much stress upon these words : "Matter consists of atoms of *different weights*, *those of the same* "*elements being all of the same weight*." We shall presently see, in order to get definite ideas, what a great deal hinges upon this reasonable concept. See part iii.

"oxygen to form 2 volumes of water vapour. Now, if 2 "volumes of hydrogen contain twice as many molecules as "1 volume of oxygen, and the resultant 2 volumes of water "vapour contain as many molecules as the original 2 "volumes of hydrogen, it is obvious that each molecule of "oxygen must be split into 2, and that the molecule of "oxygen must consist of at least 2 atoms. Again, 1 "volume of hydrogen unites with 1 volume of chlorine "to form 2 volumes of hydrochloric acid gas. The number "of molecules at the end hence remains unchanged, but "whereas each molecule then consists of hydrogen and "chlorine, it is obvious that before the union the molecules "must have consisted of hydrogen and hydrogen and of "chlorine and chlorine respectively—*i.e.*, each molecule of "hydrogen and of chlorine must have consisted of at least 2 "atoms. The molecules of a few metallic vapours consist "only of single atoms. This is the case with mercury and "zinc. The molecules of some non-metallic elements con-"sist of more than 2 atoms. For instance, molecules of "phosphorus and of arsenic consist of 4 atoms."

43. Now, let us consider the above. First let us take the following extract:

"These particles, or groups of such particles, are "supposed to be arranged in any substance at a certain "average distance from one another."

We must keep in mind the words "any substance," this is inclusive and it therefore means all substances. According to this view there is, therefore, *no permanent contact between the objects of which matter is composed—atoms and molecules*; there can be no adhesion or cohesion, because this implies permanent contact.

We are now using terms: "atoms and molecules" which are purely chemical. One of the first confusions * the general reader will have to face is that of terms used by the specialists, and we must clear away this confusion in order to get definite ideas.

44. The physicist generally uses the word "molecule" as equivalent to the chemist's word "atom." Thus J. Clerk Maxwell, who is regarded as one of the best authorities—perhaps the best—and whose works are constantly quoted, puts the issue in these words:

"A molecule of a substance is a small body such that if, "on the one hand, a number of similar molecules were "assembled together they would form a mass of that "substance, while on the other hand, if any portion of this "molecule were removed, it would no longer be able, along "with an assemblage of other molecules similarly treated, "to make up a mass of the original substance. Every "substance, simple or compound, has its own molecule. "If this molecule be divided, its parts are molecules of "a different substance or substances from that of which "the whole is a molecule. An atom, if there is such a "thing, must be a molecule of an elementary substance. "Since, therefore, every molecule is not an atom, but "every atom is a molecule, I shall use the word molecule "as the more general term."†

* "The terms molecule and atom are constantly confounded; "indeed, have been frequently used as synonymous; but the new "chemistry gives to these words wholly different meanings."—"The New Chemistry," by J. P. Cooke (10th edition), 1892, p. 98.

† "The Scientific Papers of Jas. Clerk Maxwell," 2 vols., Cambridge University Press, 1890, vol. ii, p. 363.

45. The view J. Clerk Maxwell has taken is generally adopted by the physicists, while on the other hand the chemists call the finite particle—an atom. So then we have two bodies of specialists giving different terms to the finite particle. We must elect, therefore, some definite phraseology, and we shall follow the chemists' view of calling the finite particle "an atom," as we think this is more exact.

Thus, then, we call the ultimate particle the "atom," and the smallest proportion in which atoms group themselves together we will call "the molecule." Now we have definite ideas.

46. These particles: "atoms" or "molecules," then, according to received views, are "at a certain average "distance from one another."*

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* Perhaps Professor John Parsons Cooke, in his work "The New Chemistry," puts the fundamental problem in as clear a way as it can be. He says: "Everyone knows, water can most readily be "changed both into solid ice and into aeriform steam. Let me begin "with this most familiar of all substances to illustrate what I "mean by the word molecule. When, by boiling under the atmospheric "pressure, water changes into steam, it expands 1,800 times; or, in "other words, one cubic inch of water yields one cubic foot of steam, "nearly. Now, two suppositions are possible as modes of explaining "this change. The first is, that, in expanding, the material of the water "becomes diffused throughout the cubic foot, so as to fill the space *com-* "*pletely* with the substance we call water, the resulting mass of steam "being absolutely homogeneous, so that there is no space within the "cubic foot, however minute, which does not contain its proper propor- "tion of water. The second is, that the cubic inch of water consists of "a certain number of definite particles, which, in the process of boiling,

Now the kinetic or dynamical theory also supposes that not only are these particles at a certain average distance apart, but they are also in perpetual motion of impact or near impact, and recoil, like so many atomic pugilists,

" are not subdivided, so that the cubic foot of steam contains the same " number of the same particles as the cubic inch of water, the conver- " sion of the one into the other depending simply on the action of heat

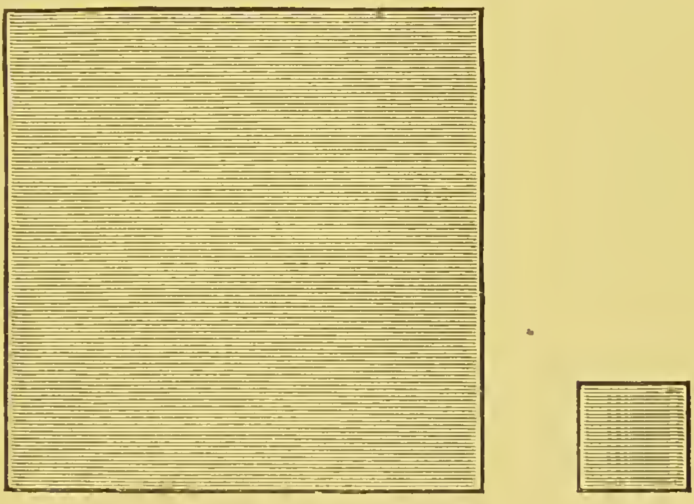

Fig. 1a.

" in separating these particles to a greater distance. Hence the steam " is not absolutely homogeneous; for, if we consider spaces sufficiently " minute, we can distinguish between such as contain a particle of " water and those which lie between the particles. Now, the small " masses of water, whose isolation we here assume, are what Avogadro " calls molecules, and, following his authority, we shall designate them " hereafter, exclusively by this word. The rude diagrams before " you will help me to make clear the difference between the two " suppositions I have made. In the first" (Fig. 1a) " we assume that " the material of this cubic inch is uniformly expanded through " the cubic foot. In the other" (Fig. 2a) " we have in both volumes a " definite number of molecules, the only difference being that these " dots, which we have used to represent the molecules, are more

hitting each other or nearly approaching each other, and recoiling in a linear direction, now hitting or approaching

"widely separated in the one case than in the other. Now, which of "these suppositions is the more probable?"*

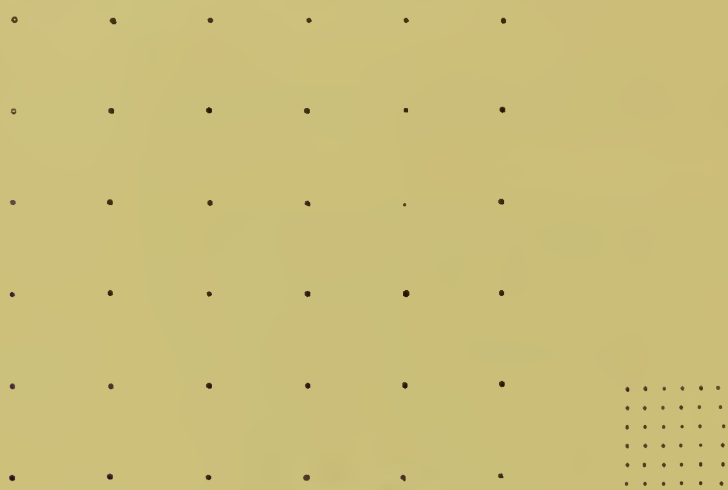

Fig. 2a.

Professor Cooke regards the first conception as impossible, indeed this is clearly so, as seen in §176, and he goes on to show the

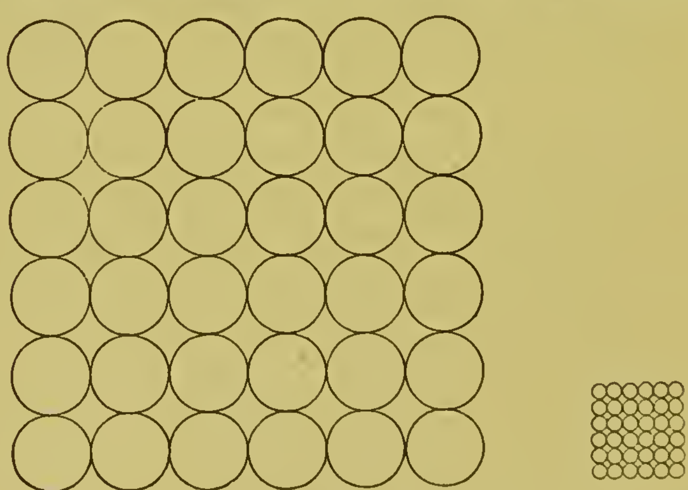

Fig. 3a.

* "The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition, 1892), p. 8.

at one point, then at another, a constant motion of impact or near impact, and recoil, and the mean or average distance they retreat from each other shows the volume of the mass of particles or the temperature of the mass.* This motion of the particles is what is termed "energy" by the physicist and chemist—hence "the effect of increased "energy must be the same as the effect which we know "follows increased temperature. . . . The temperature "of a body is the moving power of its molecules."† Nothing can, therefore, be clearer than this concept. All matter therefore consists of objects which do not cohere or adhere to each other, for even in solids this is not allowed, but are always independent of each other, and perpetually impinging or approaching, and then re-

second idea to be correct; but there is a third concept the mind can grasp, and this Prof. Cooke does not seem to have any idea of. This defect seems to be common to the minds of all physicists and chemists. Yet it is very simple, the water is built up of small particles, as in Prof. Cooke's second idea, which increase in dimensions *per-se* when they become in the condition of steam. Then Fig. 3a will represent the reaction.

* Perhaps the view can be best understood by considering a mercury thermometer. At a certain temperature, say 60° Fahr., the molecules of quicksilver are at a certain average motion of impact and recoil; they occupy a certain volume of the tube marked 60°; now apply heat to the bulb, the average motion becomes greater—*i.e.*, the molecules become a further average distance apart, and they rise in the tube to a mark on the tube, say 80° Fahr. This increase of volume is called increase of temperature, which in this case is stated to be an increase of 20° Fahr.

† "The New Chemistry," by J. P. Cooke (10th edition), 1892, p. 45.

coiling from each other at the same time they are rotating —an atomic and molecular condition of *heterogeneous* motion. Why, then, does the physicist or chemist recognise such a term as "cohesion" or "adhesion"? Such an idea is an impossibility with such a fundamental concept.

47. The idea of these various motions of the particles of which matter is built up is called the dynamical or kinetic theory. According to this view the particles are never still—their motions are *eternal* in temperate or tropical climates. We must carefully impress our minds with this idea of the specialist. Further, the concept of the physicist is: *the motions of the particles of which matter is built up is called "Heat."* *

48. Moreover, the physicist has decreed that these ultimate particles are all of the same volume, and all have the same weight, at least of each species. Now one can see how the metaphysical or mathematical concepts crop up. All these views are made to satisfy mathematical ideas. The same system which, as we have seen, cannot represent the division of an object into two pieces, which states

* "When the history of the dynamical theory of heat is com- "pletely written, the man who, in opposition to the scientific belief "of his time, could experiment, and reason upon experiment, as "Rumford did in the investigation here referred to, may count upon "a foremost place. Hardly anything more powerful against the "materiality of heat has been since adduced, hardly anything more "conclusive in the way of establishing that heat is, what Boyle, Hooke, "and Lock considered it to be, *Motion.*"—"Heat: A Mode of Motion," by Dr. Tyndall (9th edition), 1892, p. 46.

that addition is subtraction, which claims the concept of the power to annihilate objects and to create them, has decreed that the ultimate particles of matter shall be the same in dimensions and *constant in dimensions.* Nature is not consulted. Nature, says the physicist, must be subordinate to and *obey* mathematical notions.

49. Clerk Maxwell's book on Heat, and which has been just revised by Lord Raleigh, states: *

" Our molecules, on the other hand, are unalterable by " any of the processes which go on in the present state " of things, and every individual of each species is exactly " of the same magnitude, as though they had all been " cast in the same mould, like bullets, and not merely " selected and grouped according to their size, like small " shot."

Nothing can be clearer than this concept. Sir William Thomson (Lord Kelvin) follows the same view. He does not suggest there are different sizes of atoms, but takes all atoms as of the same dimensions. He says:

" To form some conception of the degree of coarse- " grainedness indicated by this conclusion, imagine a " globe of water or glass as large as a football (or say " a globe of 16 centimetres diameter) to be magnified " up to the size of the earth, each constituent molecule

* " Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 341. The reader must bear in mind in this quotation the word molecule is used in the same sense as the word atom, hence the words " of each species." § 44.

"being magnified in the same proportion. The magnified "structure would be more coarse-grained than a heap of "small shot, but probably less coarse-grained than a "heap of footballs." *

Although the article from which this extract is obtained is on "The Size of Atoms," yet it will be seen this extract calls the atom a molecule † (or, to use his phrase, "each constituent molecule"), and the whole argument is based upon the concept that atoms in dimensions are constant, not only of the same species, but of all species. This is purely a mathematical idea; we shall see experiment entirely refutes the notion.

50. In order to be quite sure that the reader shall not be misled by us we shall now give quotations from various reliable authorities to prove the statements we have made and are about to make.

"Hence part, at least, of the energy (§ 46) of a hot "body must be energy arising from the motion of its "parts, or kinetic energy. . . . Every hot body, "therefore, is in motion.‡ . . . We have now arrived "at the conception of a body as consisting of a great many "small parts, each of which is in motion. We shall call

* "Popular Lectures and Addresses by Sir William Thomson" (1889), p. 217.

† "Sir William Thomson used the word atom in the sense of "molecule, and this must be borne in mind in reading his article." —"The New Chemistry," by Dr. J. P. Cooke (10th edition), 1892, p. 28.

‡ "Clerk Maxwell's Theory of Heat" (10th edition), 1891, p. 311.

"any one of these parts a molecule* of the substance. "A molecule may therefore be defined as a small mass "of matter the parts of which do not part company during "the excursions which the molecule makes when the body "to which it belongs is hot." †

"All bodies consist of a finite number of small parts "called molecules.‡ Every molecule consists of a definite "quantity of matter, which is exactly the same for all the "molecules of the same substance. The mode in which "the molecule is bound together is also the same for all "molecules of the same substance. A molecule may "consist of several distinct portions of matter§ held "together by chemical bonds,|| and may be set in vibra-"tion, rotation, or any other kind of relative motion, but "so long as the different portions do not part company, "but travel together in the excursions made by the mole-"cule, our theory calls the whole connected mass a single "molecule.¶ The molecules of all bodies are in a state of "continual agitation. The hotter a body is, the more "violently are its molecules agitated.** In solid bodies, a "molecule, though in continual motion, never gets beyond "a certain very small distance from its original position in

* The word "molecule" here means atom or molecule.

† *Idem*, p. 312.

‡ Should read "atoms." In clause 44, Maxwell questions the existence of the ultimate particle.

§ Here should be inserted "called atoms."

|| No definition is given for "chemical bonds."

¶ This means the molecule is a group of atoms, which move about together as a whole. (*See* illustration, § 52.)

** If the volume of the matter becomes increased as it becomes hotter, it must follow "the more violent are its molecules agitated," means the further is the recoil, or the average spatial distance between the molecules becomes greater. This explains "temperature." § 46.

"the body. The path which it describes is confined within "a very small region of space.* . . . A gaseous body "is supposed to consist of a great number of molecules "moving with great velocity. During the greater part "of their course these molecules are not acted on by any "sensible force, and therefore move in straight lines with "uniform velocity. When two molecules come within a "certain distance of each other† a mutual action takes "place between them, which may be compared to the "collision of two billiard balls.‡ Each molecule has its "course changed, and starts on a new path.§ I have "concluded from some experiments of my own that the "collision between two hard spherical balls is not an "accurate representation of what takes place during the "encounter of two molecules. A better representation "of such an encounter will be obtained by supposing the "molecules to act on one another in a more gradual "manner, so that the action between them goes on for "a finite time, during which the centres of the molecules "first approach each other and then separate.|| . . .

* "Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 313.

† It is very curious to notice that Clerk Maxwell feels the importance that the sphere (see below) should be elastic, while he will not allow the spheres to touch each other. If they do not touch, the question of rigidity or elasticity ceases to be a factor! Consider the words, "When the molecules come *within a certain distance* of each other."

‡ Here observe the concept is, the molecule is a sphere when in the gaseous condition.

§ This is the idea of heterogeneous motion.

|| This is the concept of a solid elastic sphere, somewhat like a *solid* india-rubber ball. The words "action between them" imply that the molecules actually impinge on each other instead of coming "within a certain distance of each other."

"Let us next suppose a number of molecules in motion "contained in a vessel whose sides are such that if any "energy is communicated to the vessel by the encounters of "molecules against its sides, the vessel communicates as "much energy to other molecules during their encounters "with it, so as to preserve the total energy of the enclosed "system. The first thing we must notice about this "moving system is that even if all the molecules have "the same velocity originally, their encounters will produce "an inequality of velocity, and that this distribution of "velocity will go on continually. Every molecule will "then change both its direction and its velocity at every "encounter;* and, as we are not supposed to keep a "record of the exact particulars of every encounter, these "changes of motion must appear to us very irregular, if "we follow the course of a single molecule. If, however, "we adopt a statistical view of the system, and distribute "the molecules into groups, according to the velocity "with which at a given distance they happen to be "moving, we shall observe a regularity of a new kind "in the proportions of the whole number of molecules "which fall into each of these groups."†

It is questionable if this last quotation is intelligible; we have, however, to keep in view one clear idea of the physicist—viz., that the dimensions of *the finite particle are always constant,*‡ *and the motions of these*

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* *i.e.* the motion is heterogeneous.

† "Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 315.

‡ Prof. Cooke goes even further and deprives the atom of every inherent power:—"As I conceive of them, the ultimate particles of "matter are wholly inert and passive, simple magnitudes, nothing

particles, which is called "Heat," is heterogeneous. This also applies to solid, liquid and gaseous matter.

"If a molecule were a mathematical point endowed with "inertia and with attractive and repulsive forces,* the only "kinetic energy it could possess is that of translation as a "whole. But if it be a body having parts and magnitude, "these parts may have motions of rotation or of vibration "relative to each other, independent of the motion of the "centre of gravity of the molecule. We must therefore "admit that part of the kinetic energy of a molecule may "depend on the relative motions of its parts. We call this "the Internal energy, to distinguish it from the energy due "to the translation of the molecule as a whole. The ratio "of the internal energy to the energy of agitation may be "different in different gases."†

51. So now we have the conceptions: 1st, The molecule is a sphere of constant dimensions (§ 49 and § 97) whose centre of gravity can shift; 2nd, it has a motion of translation from place to place; 3rd, a spin

"more." "The New Chemistry" (10th edition), 1892, p. 64. This is a very curious confession from a chemist who knows that if he put in contact two or more of certain substances, at ordinary temperature, violent reactions take place, even explosion, and this would appear to be the result of the inherent properties of the molecules of which the substances are composed. If the ultimate particles are inert and passive, how can they have different weights? "The molecule of "Oxygen must weigh sixteen times as much as the molecule of "Hydrogen" (*idem* p. 74).

* If a point has no dimensions, *i.e.*, is space, how can it have attraction and repulsive forces?

† "Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 317.

or motion of rotation ; and 4th, a vibration of movement, a shivering motion, to and fro—impact and recoil. The one dominant idea remains, and may be expressed thus : 1st, the dimensions of the atom of which the molecule is formed is a constant ; 2nd, the sum of the motions of atoms is Heat ; 3rd, the volume or space occupied by a given quantity of atoms or molecules, resulting from the motion, is temperature.

52. With the concept given we fail to grasp what is meant by "internal energy." It implies that ALL matter is what the chemists call molecular matter—that is, there can be no matter built up of elementary atoms only. As we understand the term, it is the relative motion of the atoms to form the molecule (or the special vibrations of the atoms of which the molecule is formed), but the evidence before us is that matter consists of atoms as well as molecules. Thus the chemist states: Hydrogen is matter consisting of objects of one species, and not of compound objects—mixed species. This gas obeys the same laws, as far as Heat is concerned, as compound gases, for instance carbonic acid gas. The physicist's concept may be illustrated thus, Fig. 3, where each group of atoms is called a molecule, the atoms held together by imaginary bonds illustrated by springs. Thus each group of atoms vibrate amongst themselves, being the internal vibration of the molecule, and over this

vibration we have the vibration between group and group, molecule and molecule.

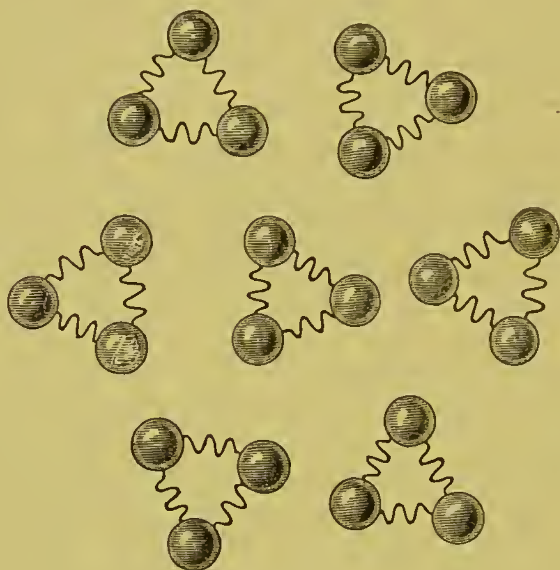


Fig. 3.*

Yet the physicist and chemist call such a group a sphere! (§ 97.)

53. We will now leave Clerk Maxwell, and go to another text-book. We will take "Deschanel's Heat," by Professor Everett. The copy we will quote from is the 11th edition, dated 1889, and revised to date. We cannot find that the kinetic theory is applied to solids or liquids in this work, as Maxwell does (§ 50). The author wisely steers clear of this trouble, and

* From Tyndall's "Heat: A Mode of Motion" (9th edition), 1892, p. 142. Here it must be observed, the group of atoms—the molecule, is not a sphere. (*See* clause 97.) The concept is untenable.

confines himself simply to measurements—equations and ratios, but when he approaches gases he gives:

"*The Kinetic Theory of Gases.*—According to the theory "of the constitution of gases which is now generally "accepted and is called by the above name, a simple gas "consists of a number of very small and exactly equal "particles, called atoms or molecules, moving about with "various velocities and continually coming into collision "with one another and with the sides of the containing "vessel. The total volume of the particles themselves is "very small compared with the space in which they move, "and consequently the time during which a particle is "in collision with other particles is a very small part of its "whole time.* Each particle is highly elastic. Its "shape can be changed by the application of external "forces; but it springs back when left to itself and "executes vibrations, which we may compare to those "of a tuning-fork or a bell. These are the cause "of the peculiar features which are detected in the "light of an incandescent gas when analysed by the "spectroscope. It can also, like any other free body, have "a rotatory or spinning motion. The kinetic energy of a "particle is accordingly composed of three parts, one due "to its vibration, another to its rotation, and a third to its "translation. This third part, which is usually greater "than the other two, is called the *energy of agitation*. The "other two are included together under the name of "*internal energy*, which may be defined as the energy

* This is the concept that the dimensions of the finite particles are constant, and the motion of these particles, called Heat, is heterogeneous. The word collision implies absolute contact and then a recoil, as in the motions of billiard balls.

"of the relative motion of different parts of the same "molecule." *

54. So we have here new properties given to the atom or molecule of "a simple gas," whatever that may mean, namely, that it is *highly elastic*, and that it vibrates like a tuning-fork or a bell, that it comes into collision, that is there is impact,† and not, as Clerk Maxwell puts it, the molecules "come within a certain distance of each other." Well, what is meant by the word "elastic"? We may illustrate a solid india-rubber ball—that is elastic. We can also illustrate a hollow india-rubber ball distended with air, which gives the concept of highly elastic. Does the author mean these particles—these atoms, or molecules of "simple" gases *are like very minute elastic spheres the size and shape of which can be constantly changed by internal and external forces*, and the atom or molecule springs back to its original condition when left to itself and executes vibrations? Again, what is meant by vibrations? This is a vague term; it may mean a motion too and fro, a very quick alternate motion of translation in space, or it may mean a rhythmical motion *of alternate expansion and contraction of the object itself* as when an india-rubber balloon is expanded by the inflow of air and contracted by the outflow of air;

* Page 490.

† Both Prof. Cooke, "The New Chemistry," 10th edition, 1892, p. 47, and Prof. Tilden, "Watt's Manual of Chemistry," 1889, p. 27, regard the reaction as that of impact and recoil, but in pages 30 and 49 Prof. Cooke contradicts himself. (*See* § 56.)

this would be a true vibration if done quickly. It would be a similar rhythmical motion to the motion of the heart. Anyhow, whatever is meant by the expressions used by the author, we would beg the reader to carefully remember the words in italics. It is not necessary to go further into text-books; they mostly copy each other, and to quote from two good ones is practically to quote from all.

55. Leaving the text-books, we find by far the most concise description of the concepts of the physicist in Stallo's "Concepts and Theories of Modern Physics" (2nd edition, p. 85, chap. vii.), "The theory of the atomic "constitution of matter"—a chapter all who take interest in these important fundamental questions should read. In describing the theory, he says:

"1. *Atoms are absolutely simple, unchangeable, indestruc-"tible; they are physically, if not mathematically, indivisible.*

"2. *Matter consists of discrete parts, the constituent atoms "being separated by void interstitial spaces. In contrast to the "continuity of space stands the discontinuity of matter. The "expansion of a body is simply an increase, its contraction a "lessening, of the spatial intervals between the atoms.*

"3. *The atoms composing the different chemical elements "are of determinate specific weights, corresponding to their "equivalents of combination.*"

"To avoid confusion, I purposely ignore, for the mo-"ment, the distinction between *molecules*, as the ultimate "products of the physical division of matter, and *atoms*, "as the ultimate products of its chemical decomposition, "preferring to use the word *atoms*, in the sense of the least "particles into which bodies are divisible by any means."

56. If the physicists' views (including of course Clerk Maxwell's and Lord Rayleigh's)* be correct, the atom is a body always of constant volume and inelastic; but as we know matter, when it is heated, expands,† and when it is chilled it contracts, we are left with the only concept possible: the motions of impact and recoil—*i.e.*, vibration—are the motions which constitute the phenomena called *Heat* or *Cold*, the greater motion being Heat, the lesser motion being Cold. In Professor Everett's view, however, a new factor is imposed in the idea that the "atom or molecule" is not a nearly rigid body, but is "highly elastic." He does not give any information which leads us to definite ideas as to whether it increases or decreases *per se* in volume? It is a pity he is so vague. We understand the word "elastic," as used by the physicist, to mean an object somewhat like a *solid* india-rubber ball, so that what it may loose by pressure in one part it gains by expansion in another way, and thus the volume is constant; it is not like an elastic hollow india-rubber ball, which may be altered in dimensions as when air is forced into it, and tending to return to its former

* We take it Lord Rayleigh is of opinion that Clerk Maxwell's views are correct, as he has so very recently revised his work (1891) and has made no observation as to Maxwell's views, whereas he has corrected any errors and brought the work up to date.

† There is only one exception to this law, *i.e.*, during the time matter crystallizes; this law does not then always hold good. (*See* clause 180.)

dimensions by exuding air. Both are motions of elasticity.

To complete the confusion which exists, let us consider the following:

"In a state of perfect gas, it is assumed that the "molecules are so widely separated that they exert no "action upon each other." * . . . "In the gas the "molecules are separated beyond the sphere of each "other's influence," † so here the conception of vibration of impact and recoil is got rid of! Let the reader consider the experiment explained in §§ 145, 146.

57. We now proceed to consider the objections to the *generally received view,* and we will illustrate our difficulties by three fundamental examples. We may, however, here observe our impression is that the general view understood but not definitely expressed is: the ultimate particle is *infinitely hard,* having no elasticity. If, however, Professor Everett's view be correct (as we understand it) that the "atom or molecule" is "highly elastic," but does not increase or decrease in volume, then this view does not effect the argument. With either view the issue is centred in the concept that *the volume of the finite particle is constant.*

58. *First Objection.*—If one goes to the British Museum and asks the authorities to show the oldest dated coin in the Museum, the date of which the authorities

* "The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition, 1892), p. 30.

† *Idem,* page 49.

can vouch as correct, a coin a copy of which is here drawn (Fig. 4) will be produced.

It is a silver coin, and as perfect as when it left the die. The contour and impressions are sharp and well marked, and there is nothing to make one think there is the slightest alteration in either, since the coin was made. It is an Egyptian coin of the reign of Ptolemy II., and is dated B.C. 260. It therefore is over 2,000 years old, and the kinetic theorists tell us

Fig 4.

that the particles (atoms or molecules) of which this coin is built up have been in a constant state of *hetero-geneous* motion for these 2,000 odd years, a motion where the particles are impacting and recoiling, and after impact "each molecule has its course changed and "starts on a new path;" that this impact (or near impact) and recoil differs in degree according to the temperature of the weather and consequently of the coin—that is, the volume of the coin has been ever changing for over 2,000 years; that, inasmuch as the temperature never gets to absolute zero, this molecular motion has been perpetual. The coin, therefore, being composed of objects

in a constant or perpetual condition of heterogeneous motion, there can be no adhesion or cohesion, because the molecules are "a certain average distance from one another"! Reader, use your good sense,* can you imagine such a condition possible? Should not the contour and configuration of the coin, with its parts in heterogeneous motion, have dissolved, and should not the coin under such present condition be plastic or liquid instead of being rigid? —yet a mathematically trained mind cannot see this!

59. The specialist tells us, first, the atoms or molecules of the coin adhere or cohere, hence it is "solid"; then he tells us the atoms do not adhere or cohere because they are in a state of independent and heterogeneous motion, and they are a certain average distance apart. Well, inasmuch as mathematics can prove addition is subtraction, why does not the physicist go to the fullest terms of absurdity and say: our mathematical definition of a square is a circle, a cube is a sphere, a straight line is a crooked line, motion is an object at rest, and finally cohesion is separation or a solid is a liquid? Is it not wonderful that minds trained by a severe and rigid system cannot see the utter absurdity of the situation?

60. *Second Objection.*—Now consider the second illustration. Take a volume of one cubic inch of water, subject it to the action of the "galvanic current" (what-

* "Science is, I believe, nothing but *trained and organised common* "sense."—J. H. Huxley, "Lay Sermons, Addresses, and Reviews," 1893, p. 66.

ever this term means we do not at present know), and thus by the action of what is called "electrolysis," the molecules of which the water is composed become unbonded * (*i.e.*, done something to, which we do not at present understand). The water ceases to be liquid and becomes gaseous. The water molecule has suffered a state of change, its properties have been entirely altered. The chemist states the water molecules are converted into molecules of hydrogen gas and molecules of oxygen gas. But what is the difference in volume of the molecule of water compared to the volume of the molecules of the mixed gases. According to Cooke† it is a ratio of 1 to 1,800—that is to say, the cubic inch becomes 1,800 cubic inches of gas. Let us picture to our minds what this means. We cut a cube of wood one inch every way in dimensions, *i.e.*, a cubic inch, and make a box 10 inches square at ends and 18 inches long. We compare one with the other, and then we realise the relative dimensions of the cubic inch of water compared to the immense increase of volume of the gases of which water is composed.

What does the "unbonding" mean, according to the kinetic theory? Why this, inasmuch as the finite objects are constant in volume, therefore the only deduction possible

* We are not sure we are right in using this word, but as the specialist calls chemical combination the "bonding" of atoms, the best expression for undoing that combination we think is "unbonding."

† "The New Chemistry," by J. P. Cooke, LL.D. (10th edition, 1892), p. 218.

is: that in the gaseous condition they must be at a very considerable average distance apart in order to occupy so great a volume as 1,800 cubic inches. Now comes the difficulty: The molecules of gases occupying this large volume, according to Clerk Maxwell, "are in a state "of continual agitation. The hotter a body is, the "more violently are its molecules agitated."* . . . "A gaseous body is supposed to consist of a great "number of molecules moving with great velocity. "During the greater part of their course these molecules "are not acted on by any sensible force, and therefore "move in straight lines with uniform velocity. When "two molecules come within a certain distance of each "other, a mutual action takes place between them, which "may be compared to the collision of two billiard balls." †

Maxwell afterwards slightly qualifies this concept in stating that these are not quite hard and inelastic balls, and they do not come in contact. Well then, the difference between the liquid and the gaseous is simply a ratio of great atomic or molecular motion in the latter as against a very small amount of molecular motion in the liquid, and, according to the physicist, *this motion is Heat;* moreover, the greater motion is increase of temperature, the lesser motion is decrease of temperature (§ 46). The concept may be thus expressed: when you put a thermometer

* "Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 313.

† *Idem*, p. 314.

into a medium having a certain motion of its ultimate constituents, the motion is communicated to the glass molecules of which the glass bulb is composed, the glass molecules in their turn communicate their motion to the mercury, the mercury molecules increase in vibration in consequence of receiving an increase of motion from the objects they are immersed in; they require room for this increase of motion, and thus the mercury molecules occupy a larger volume; they can only rise in the tube, and this rising in the tube is what is called increase of temperature. Therefore increase of temperature is increase of atomic or molecular motion. Now it is most certainly obvious with such a view as this is, inasmuch as the atoms and molecules of which the gases consist are in an enormous state of atomic and molecular motion compared to their motion when bonded in the condition of water molecules, then when the thermometer is removed from the liquid—water, and plunged into gases, this increased motion should be communicated through the glass to the mercury in the thermometer, and this should rise very considerably, and thus gases should register very high temperatures indeed, the increment of the motion being as 1 to 1,800. But what is the fact: *the temperature of the gas is exactly the same as was the water as measured by the thermometer!* —proving there is no more motion in the gas than there is in the water, so the dynamical theory cannot be true. Well may Clerk Maxwell express doubts of this theory, for he states:

"The evidence for a state of motion, the velocity of "which must far surpass that of a railway train, existing in

"bodies which we can place under the strongest micro-"scope, and in which we can detect nothing but the most "perfect repose, must be of a very cogent nature before we "can admit that heat is essentially motion."*

These very important words of Maxwell's should be well borne in mind.

61. *Third Objection.*—To understand the third negative illustration we must use the thermopile and galvanometer. As the general reader may not be aware of the properties of these valuable instruments, and as it will be necessary to make our work complete, we must describe them; we may as well do this at once. The astatic galvanometer consists of a double magnetised needle, made up of two needles rigidly fastened together so that their poles are kept always opposite.

The double needle is suspended by means of a fine thread of unspun silk. The lower needle is so placed that it swings round within a coil of insulated copper wire. The upper needle appears above a marked dial, generally of cardboard, on which degrees from 0 to 90 each way are marked, or divided into degrees somewhat like the face of a compass. The

* "Theory of Heat," by J. Clerk Maxwell, p. 309 (10th edition, 1891). Probably one of the most striking pieces of evidenee against the idea that Heat is molecular motion is found in the recent discoveries of Prof. Dewar: Liquid oxygen, which is so cold, under certain conditions, that air, coming in eontact with the vessel which holds it, becomes liquid. Now this liquid oxygen at this very low temperature is in a state of ebullition, it boils! Here we have intense molecular motion accompanied with intense cold!

needles therefore swing together. The engravings will clearly explain the instrument. In Fig. 5, S is the filament of thread, B C the two needles, which are marked,

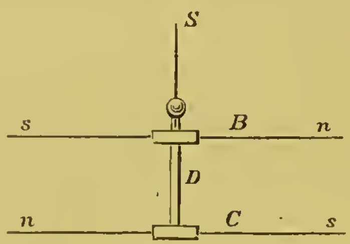


Fig. 5.

n being north pointing, and s south pointing; they are bound together by the metal connection D. The following will show the galvanometer * with thermopile complete:

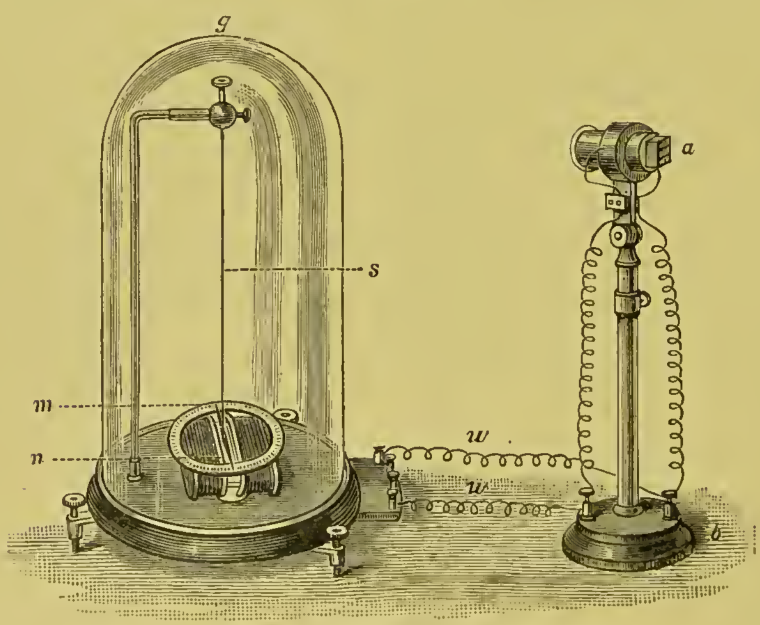


Fig. 6.

* In using the galvanometer it is best to place it on an accurately levelled shelf affixed to a solid wall; this prevents any vibration, and the needle then responds to the current in a very satisfactory way.

Where *g* is a shade to protect the galvanometer from air currents, *s* is the filament of unspun silk, and *m* and *n* the needle over the cardboard dial. Below the dial is the coil of insulated covered wire, the ends of which are connected with the wires *w w* and these connect with the other instrument, the thermopile *a b*. In the coil of wire the lower needle now swings. This will not be seen in the engraving. When at rest, that is when no current is passing through the coils of wire, the needles set themselves to a certain point of the compass, but not true north and south. Now it has been found by experiment that when two different metals are soldered together, as two ends of two bars may be (see also § 144), and the two other ends are connected with the copper wires *w w* of the galvanometer: then if at their point of junction Heat is applied, a current of something—what it is we do not at present know—goes through the wires. The result is, the needles of the galvanometer are deflected. With a single pair of metals, however, this current is feeble when the Heat applied is very small, but the intensity of the current may be increased by increasing the number of pairs so that a larger amount of Heat may be collected and a large deflection produced. It is also found by experiment that the best metals for the purpose we have in view are antimony and bismuth, and in practice a number of small bars of these metals are

soldered together at each end. The diagram below explains the mode of connection.

Where *b*,—the dark bars, are bismuth; and *a*,—the light bars, are antimony. The whole group of bars are connected together by wires with *G*, which in the diagram represents the galvanometer. The arrows represent the direction of the current, supposing the junctions at *b b* are warmed. In order to

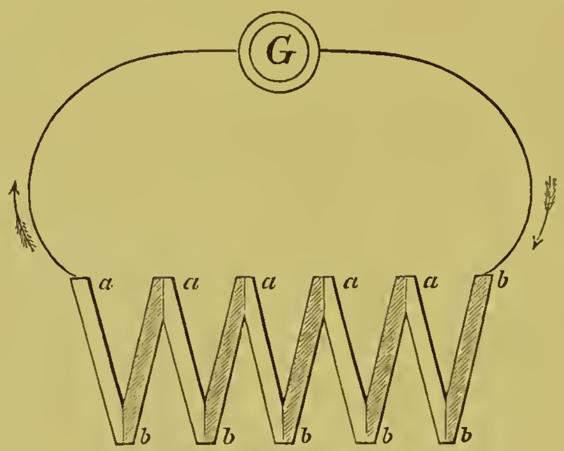
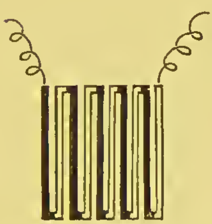


Fig. 7.

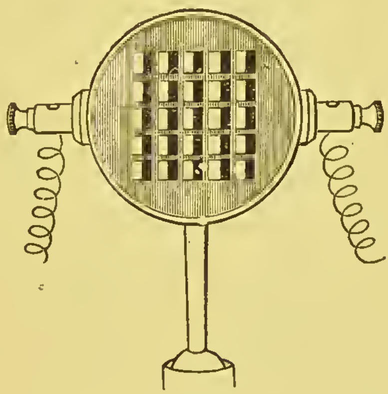
make the apparatus compact, the bars are put close together, so that they become in appearance a square block, as illustrated in Figs. 8 and 8a.

The faces of the square block are exposed on the front and back of the instrument, while the sides are protected by a brass casing. This is a thermopile. Now when these instruments (the galvanometer and thermopile) are joined up, as shown in the engraving (Fig. 6), the slightest amount of Heat applied to the

face (Fig. 8a) of the thermopile will quickly send the needle of the galvanometer from 0° to 90° in one direction, while if the back of the thermopile be heated the needle swings in a corresponding manner in a contrary direction. Thus suppose we were to mark 90° on the scale of the galvanometer W, and the opposite 90° we were to mark E, as is done in a compass, then if we heated the front of the thermopile the needle would go in the direction



SECTION OF THERMOPILE.
Fig 8.



FACE OF THERMOPILE.
Fig. 8a.

of E, but if we heated the back the needle would go in the direction of W. If, however, we chill the front or the back of the thermopile, the needle will go in the contrary direction to what it would if we heated it. By confining ourselves to the front only, the reactions become very simple. Thus we heat the front and the needle moves to E, or we chill the front and the needle goes to W. We are particular in describing this instrument, which is of

more value for experiment than the thermometer; in fact, as we shall see, the instrument records a different quality of reaction than the thermometer. How sensitive the instrument is! See, just breathing on the face of the thermopile causes the needle to go quickly round to 90°, and then it oscillates less and less, and gradually comes back to zero (0°). If, however, we fix a silver-lined cone to the apparatus so that the so-called Heat rays are collected and condensed on the face of the thermopile, a lighted candle many yards away will cause a deflection!

62. Well we have now our apparatus. Here is a steel bottle containing hydrogen * gas (any other gas, or mixture of gases, air, &c., will answer as well) which has by pressure been forced into the bottle.† If we turn on the tap the gas will squirt out in a stream, the atoms of which the gas is composed being forced out by their own inherent power of expansion. We present this stream of moving atoms to the thermopile. These atoms,‡ then, which are generally considered infinitely hard, or, according to Maxwell's views, nearly hard, rigid objects, but always

* We illustrate hydrogen because it is of one class of objects. It is not a compound gas like carbonic acid gas.

† These steel bottles are now familiar to nearly every one, being bottles of compressed gases, commonly used for the oxy-hydrogen light for the lantern, and so want no further description.

‡ The chemist states that these atoms, under these conditions, exist in pairs—each pair being "bonded"; hence each pair is a "molecule."

of constant dimensions like very minute *solid* india-rubber balls, impact or strike the face of the thermopile. As they come out of the bottle they spread out or become further apart; this latter reaction is what is called "rarification," so that their mean distance apart becomes greater the further they are from the mouth of the steel cylinder. Here is by no means a simple re-action, but we must note the increase of volume of the mass. The further the atoms are from the mouth of the bottle the further they separate from each other —that is, if they are constant in volume. *If this force or energy of impact of atoms on the face of the thermopile is Heat,* as the kinetic theorists state, the galvanometer should give that swing of the needle which denotes the reaction of Heat; *instead of which it gives the reaction of cold.* But now let us alter the experiment and instead of using the compressed gases we will only compress gases very slightly such as will be only necessary to get a motion of impact. For this purpose we will use a pair of bellows, and we will blow upon the thermopile as in the illustration (Fig. 9).* Here we have the same order of motion as from the steel cylinder, viz., impact of the atoms upon the thermopile. What is this reaction? Why, exactly the reverse of the previous experiment—that is, the reaction of Heat. This experiment is illus-

* If the instruments are good, even fanning the face of the thermopile with an ordinary fan will produce a deflection in the direction of Heat!

trated by Dr. Tyndall to prove that Heat is molecular motion.* It must follow, therefore, the same motion of impact of the atom or the molecule, differing only in degree, produces the reactions both of Heat and Cold. What is most important to keep in view is the *greater* force of impact produces Cold, and the *lesser* force of impact produces Heat. The force of impact is a measure

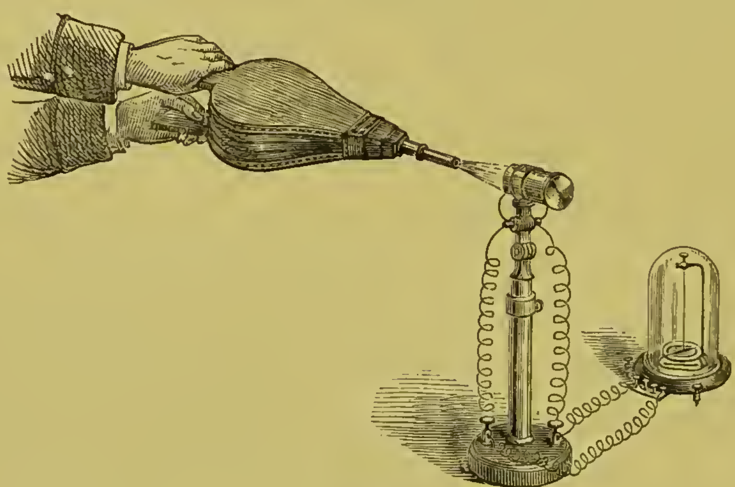


Fig. 9.

of energy—work done. How then can Heat be molecular motion?

63. There is, however, a very striking way of combining these two experiments. Take a piece of glass tubing about $\frac{3}{8}$ in external diameter, *a* (Fig. 10). The size of the glass tube is not material: insert it into india-rubber tubing *b*, connecting with a foot blower or bellows. Place the open end in front of the thermo-

* "Heat: A Mode of Motion" (9th edition), 1892, p. 16.

pile *c*. It will be noticed that the orifice *d* of the glass tubing is suddenly contracted; this is the important point. Now if we blow air by means of the bellows through the glass tube *a*, a constant current of air, consisting of molecules which are said to be like so many minute *solid* india-rubber balls, rush past *d* with

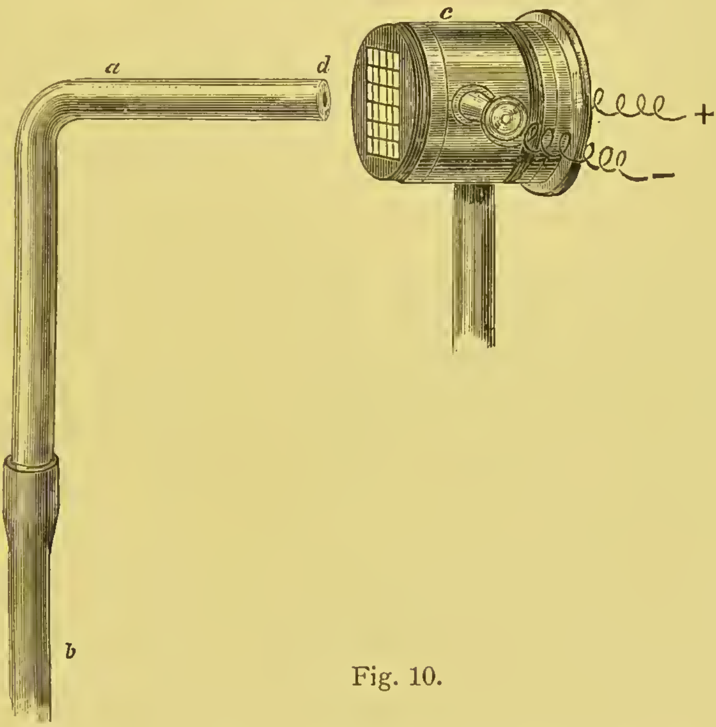


Fig. 10.

great velocity, and with considerable force they impinge upon the face of the thermopile. If the thermopile be close to the orifice *d*, say within $\frac{1}{2}$-inch, the reaction denoted by the galvanometer is that of Cold; whilst if the thermopile be removed further away from the glass tubing, then the reaction of Heat is recorded by the galvanometer. A moment's reflection will show the reader

there is a more powerful motion of impact or force when the thermopile is close to the orifice than when it is further away. If this motion of impact of these objects be Heat, then there should be a greater reaction of Heat as recorded by the galvanometer when the thermopile is near the orifice *d* than when further away. Instead of Heat, however, being shown, we have the reaction of Cold recorded in a most marked manner—a deflection of even 90°!

64. No doubt whenever we have the addition of Heat to matter we have atomic or molecular displacement—this is atomic or molecular movement; and whenever we take Heat from matter, *i.e.*, to cool or chill it, we have atomic or molecular movement; but to say therefore Heat is molecular motion, and nothing but molecular motion, is, we venture to say, simply confounding cause with effect. (§ 117.)

65. The three objections we have given and illustrated by experiment, and which repudiate the concepts of the physicists, may be amplified almost to any extent—they are three fundamental illustrations; it is impossible to get away from the overwhelming evidence of these experiments. It may be just as well to refer here to the valuable observations of J. B. Stallo in his work, "The Concepts and Theories of Modern Physics." * When treating of the kinetic theory of gases, he says:

* 2nd edition, 1885, pp. 105 to 128.

"The assumptions of this theory are that a gaseous "body consists of a great number of minute solid particles "—molecules or atoms—in perpetual rectilinear motion, "which, as a whole, is conserved by reason of the absolute elasticity of the moving particles, while the directions of the movements of the individual particles are "incessantly changed by their mutual encounters or "collisions. The colliding particles are supposed to act "upon each other only within very small distances and "for very short times before and after collision, their "motion being free, and consequently rectilinear, in the "intervals between such distances and times. The "durations of the rectilinear motions in free paths are, "moreover, assumed to be indefinitely large as compared with the durations of the encounters and of "the mutual actions. . . . The fundamental fact to "be accounted for by this theory is that gases are bodies "which, at constant temperatures and in the absence "of external pressure, expand at even rate. From this "fact the two great empirical laws, so called, expressive "of those physical properties of a gas which are directly "attested by experience, are the necessary and immediate "consequences, being, indeed, nothing more than partial "and complementary statements of it. The limitation "of gaseous volume being produced by pressure alone "—the cohibition of the bulk of a gas being due *solely* to "pressure—it follows that it must be proportional to it; "in other words, that the volume of a gas must be "inversely as the pressure; and this is the law of Boyle "or Mariotte. Again: temperature is measured by the "uniform expansion of a column of gas (in the air "thermometer); hence, if all gases expand equally, "temperature is proportional to the volume of a gas and "conversely; this is the law of Charles. The foregoing

"real definition (*i.e.*, exhibition of the properties) of a "gas applies only to ideal or perfect gases. In actual "experience we meet with no gas which, in the absence "of pressure, expands with absolute uniformity; and for "that reason we do not know experimentally of any "gas behaving in strict conformity to the laws of Boyle "and Charles. Moreover, we are unable directly to "observe a gas which is wholly frée from pressure; the "datum of experience is simply that gases expand (other "things being equal) in proportion to the diminution of "the pressure to which they are subjected. But in the "case of many gases—those which are either wholly "incoercible, or coercible (*i.e.* reducible to the liquid "or solid state) with great difficulty, and of nearly all "gases at very high temperatures—the deviation from "uniformity of expansion is very slight.

"Now, how does the kinetic theory of gases explain the "experiential fact or facts just stated? It professes to "explain them on the basis of at least three arbitrary "assumptions, not one of which is a datum of experience, "viz.:

"1. That a gas is composed of solid particles which "are indestructible and of constant mass and volume.

"2. That these constituent particles are absolutely "elastic.

"3. That these particles are in perpetual motion, and, "except at very small distances, in no wise act upon each "other, so that their motions are absolutely free and there-"fore rectilinear.

"I refrain from adding a fourth assumption—that of the "absolute equality of the particles, in mass at least—"because it is claimed (though unjustifiably) to be a "corollary from the other assumptions.

"... The second assumption asserts the absolute "elasticity of the constituent solid particles. What is the "import and scope of this assumption? The elasticity of a "solid body is that property by means of which it occupies, "and tends to occupy, portions of space of determinate "volume and figure, and therefore reacts against any "force or stress producing, or tending to produce, an "alteration of such volume or figure with a counter-force "or stress which, in the case of perfect elasticity, is "exactly proportional to the altering force. Now, it is "seen at once that the property—the *fact*—thus assumed "in the constituent solid, includes the very fact to be "accounted for in the gas. A perfect gas reacts against "a stress tending to reduce its volume with a spring "proportional to the stress; and for this reason gases "are defined as elastic fluids. This resilience of the gas "against diminution of volume is obviously a simpler "fact than the rebound of a solid against both diminution "*and increase* of volume, *in addition to the reaction against a* "*change of figure*. The resistance to *several* kinds of change "implies a greater number of forces, and is therefore a "more complex phenomenon, than the resistance to *one* "kind of change.

"It thus appears that the presupposition of absolute 'elasticity in the solids, whose aggregate is said to consti- "tute a gas, is a flagrant violation of the first condition of "the validity of an hypothesis—the condition which re- "quires a reduction of the number of unrelated elements "in the fact to be explained, and therefore forbids a mere "reproduction of this fact in the form of an assumption, "and *a fortiori* a substitution of several arbitrary assump- "tions for one fact. Manifestly the explanation offered by "the kinetic hypothesis, in so far as its second assumption "lands us in the very phenomenon from which its starts,

"the phenomenon of resilience, is (like the explanation of "impenetrability, or of the combination of elements in definite proportions by the atomic theory) simply the illustration of *idem per idem*, and the very reverse of scientific "procedure. It is a mere *versatio in loco*—movement without "progress. It is utterly vain; or rather, inasmuch as it "complicates the phenomenon which it professes to explicate, it is worse than vain—a complete inversion of the "order of intelligence, a resolution of identity into difference, "a dispersion of the One into the Many, an unravelling "of the Simple into the Complex, an interpretation of the "Known in terms of the Unknown, an elucidation of the "Evident by the Mysterious, a reduction of an ostensible "and real fact to a baseless and shadowy phantom. . . . "I proceed to consider the third assumption of the kinetic "hypothesis. This assumption is an unavoidable supplement to the initial theoretical complication of the phenomenon of elasticity, produced by the arbitrary substitution "of the resilience of a solid against increase or diminution of volume and change of figure for the reaction "of a gas against diminution of volume alone. To get rid "of one gratuitous feature of the hypothesis (the addition "of the rebound against dilatation and distortion to that "against compression) and to bring it into conformity with "the fact to be explained, it becomes necessary to add "another arbitrary feature—to endow the parts with "incessant rectilinear motion in all directions. In respect "to this assumption, which, like other assumptions of the "mechanical theory, is based upon a total disregard of the "relativity and consequent mutual dependence of natural "phenomena, it is to be said, for the present, that it is "utterly gratuitous, and not only wholly unwarranted by "experience, but out of all analogy with it. Bodies which, "except on the very verge of immediate contact, move

"independently without mutual attraction or repulsion or "any sort of mutual action and thus present perfect "realizations of the abstract concept of free and ceaseless "rectilinear motion, are unheard-of strangers in the wide "domain of sensible experience. So complete an abandon-"ment of the analogies of experience is all the more sur-"prising in view of the circumstance that the atomic "hypothesis, whereof the kinetic theory of gases is a "branch, is confessedly a concretion of suggestions derived "from celestial mechanics. There is hardly a treatise on "modern physics in which the atoms or molecules are not "compared to planetary or stellar systems. . . . But "the bodies with which celestial mechanics deal are all "subject to the law of attraction; and the import of the "very first theorem of Newton's Principia is, that these "bodies, if their motions are at any moment out of the same "straight line, can never collide, but must always move in "curved orbits at a distance from each other. Oblique "impacts between them productive of rotations as well as "of deviations from their paths before impact, as they are "imagined by Clausius and the other promoters of the "kinetic theory, are impossible. And this is true, not only "when the mutual actions of the bodies vary inversely as "the squares of their distances, but whenever they vary as "any higher power of these distances—a proposition to be "borne in mind in view of certain speculations by Boltz-"mann, Stefan, and Maxwell, of which I shall presently "speak."

"There is another very extraordinary, and, in the light "of all teachings of science, unwarrantable feature in the "assumption respecting the movements of the alleged solid "constituent particles. I allude to the absolute discon-"tinuity between the violent mutual action attributed to "these particles during the few instants of time before and

"after their collisions, and their total freedom from mutual "action during the comparatively long period of their "rectilinear motion along 'free paths.' And this leads me "to say a few words in regard to certain subsidiary assump-"tions made by Maxwell and others in order to account "for the anomalies exhibited by gases of different degrees of "coercibility in their deviations from Boyle's and Charles's "law. Maxwell assumes that the gas molecules are neither "strictly spherical nor absolutely elastic, and that their "centers repel each other with a force inversely propor-"tional to the fifth power of their distance; * while Stefan "endeavours to adjust the hypothesis to the phenomena in "question by postulating that the molecules are absolutely "elastic and perfect spheres whose diameters are inversely "proportional to the fourth roots of the absolute tempera-"tures of the gases. These assumptions, which are fatal to "all claims of simplicity preferred on behalf of the kinetic "hypothesis, are in no sense an outgrowth of its original "postulates; both are purely gratuitous as well as without "experiential analogy, and the first of them, that of "Maxwell, is in direct defiance of all the inductions from "the wide range of actual observation. They are both "mere stop-gaps of the hypothesis, peace offerings for its "non-congruence with the facts, pure inventions to satisfy "the emergencies created by the hypothesis itself.

"It were work of supererogation to review in detail "the logical and mathematical methods by which it is "attempted, from an hypothesis resting on such "foundations, to deduce formulæ corresponding to the "facts of experience. I may be permitted to say, "however, that the methods of deduction are only less

* "Since this was written, Maxwell himself has abandoned this assumption as not conformable to the facts."

"extraordinary than the premisses. To account for "the laws of Boyle and Charles, resort is had to the "calcalus of probabilities, or, as Maxwell terms it, the "method of statistics. It is alleged that, although the "individual molecules move with unequal velocities, "either because these velocities were originally unequal, "or because they have become unequal in consequence "of the encounters between them, nevertheless, there "will be an average of all the velocities belonging to "the molecules of a system (*i.e.*, of a gaseous body) "which Maxwell calls the 'velocity of mean square.' "The pressure, on this supposition, is proportional to "a product of the square of this average velocity into "the number of molecules multiplied by the mass of "each molecule. The product of the number of mole- "cules into the mass of each molecule is then re- "placed by the density—in other words, the whole "molecular assumption is, for the nonce, abandoned— "and the velocity is eliminated as representing the "temperature; it follows, of course, that the pressure "is proportional to the density.

"Similar procedures lead to the law of Charles "and the 'law' of Avogadro (according to which the "number of molecules in any two equal volumes of "gases of whatever kind is the same at the same "temperatures and pressures—a law which is itself a "mere hypothesis). It is claimed, on statistical grounds "again, that not only the average velocity of a "number of molecules in a given gaseous body is the "same, but that 'if two sets of molecules, whose "'mass is different, are in motion in the same vessel, "'they will, by their encounters, exchange energy with "'each other till the average kinetic energy of *a* "'*single molecule of either set* is the same. This,' says

"Maxwell, 'follows from the same investigation which "'determines the law of distribution of velocities in a "'single set of molecules.'* All this being granted, "the law of Charles and the law of Avogadro (called "by Maxwell the law of Gay-Lussac) are readily "derived. And at the end of these devious courses "of deduction Maxwell adds a disquisition on the "properties of molecules, in which he claims to have "made it evident that the molecules of the same sub-"stance are 'unalterable by the processes which go "'on in the present state of things, and every "'individual of each species is of exactly the same "'magnitude as though they had all been cast in the "'same mould, like bullets, and not merely selected and "'grouped according to their size like small shot,'† and "that, therefore, as he expresses it in another place, "they are not the products of any sort of evolution, "but, in the language of Sir John Herschel, 'have the "essential character of manufactured articles.'"

"Now, on what logical, mathematical, or other grounds "is the statistical method applied to the velocities of "the molecules in preference to their weights and volumes? "What reason is given, or can be given, why the masses "of the molecules should not be subjected to the pro-"cess of averaging as well as their motions? None "whatever. And, in the absence of such reason, the "deductions of the kinetic theory, besides being founded "on rickety premisses, are delusive paralogisms."

"Upon these considerations I do not hesitate to "declare that the kinetic hypothesis has none of the

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* Maxwell's "Theory of Heat" (10th edition), 1891, p. 316.

† *Idem*, p. 341.

"characteristics of a legitimate physical theory. Its "premisses are as inadmissible as the reasoning upon "them is inconclusive. It postulates what it professes to "explain; it is a solution in terms more mysterious "than the problem—a solution of an equation by "imaginary roots of unknown quantities. It is a pre-"tended explanation, of which it were unmerited praise "to say it leaves the facts where it found them, and "is obnoxious to the old Horatian stricture: *Nil agit* "*exemplum, litem quod lite resolvit.* . . . . It may "seem strange that so many of the leaders of scientific "research, who have been trained in the severe schools "of exact thought and rigorous analysis, should have "wasted their efforts upon a theory so manifestly "repugnant to all scientific sobriety—an hypothesis in "which the very thing to be explained is but a small "part of its explanatory assumptions."

The fact is, the physicist, building up his ideas almost entirely upon mathematical or metaphysical reasoning, has got much beyond his depth. He is floundering in the mysterious. Stallo, however, while he severely criticises the efforts of the physicists, offers no definite view; he does not suggest an alternative; he breaks down those notions which the physicists, when pressed hard, have already acknowledged as broken. We shall endeavour to build up, and we hope to avoid the error of the physicist by ignoring mathematical considerations, and by means of diagrams endeavouring to represent the reactions to the mind in a manner the mathematical mind cannot approach. We thus avoid the severe mental treat-

ment mathematics require and which injures the natural reasoning powers. We shall picture each unseen object to the mind as we see objects generally. We shall make these objects perform like operations to those which invisible atomic matter performs. The mathematician can do no more; he can only obfuscate all these motions, and this we hope to avoid.

66. We have now sufficiently completed our negative evidence, and we shall proceed with our positive evidence. We shall handle the matter much in the same manner as a barrister pleads his case, we shall assume our case to be the truth and the whole truth. On starting, we shall fully state the case of our client, and then we shall support it by experimental evidence, and we hope to present that evidence in such clear terms that the general reader, who is one of the jury, can fully grasp the issues and form judgment. We cannot undertake to be infallible; we shall make errors, but we will try to make few errors, and even such will be so subordinate to the main issues that they may well be left unnoticed.

PART III.

ON GRAVITATION AND WEIGHT.

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67. One of the important factors in solving the great problems under consideration is terrestrial gravitation.

What is gravitation? The metaphysician or mathematician up to the present has failed to answer this question.

"To account for the phenomenon of gravitational "attraction several theories have been advanced; but in "spite of the best efforts of mathematicians and physicists, "the real cause remains undiscovered." *

Why have they failed? Because their fundamental ideas are formed from metaphysical notions instead of being *entirely* based upon experiment or the observations of facts.

68. Take matter from the greatest depths of the earth, from the bottom of the sea, from the highest mountain, from the air above the mountain; take the meteorite which comes from space or the higher regions of the air, or take the objects cast from the bowels of the earth by volcanoes, give them to the

* Article "Gravitation," "Chambers' Encyclopædia," 1890.

chemist, ask of him—"What are these objects?" and he gives but one reply: "Each and all are masses of "matter built up of atoms," and these atoms are bonded or combined in some way which he does not understand to form the masses of solid, liquid, and gaseous matter of which the world, as a whole, is composed. The fact is simple, clear, undeniable, and evident to our common-sense, or one may say to the whole of our senses, as well as to our reason. At the present moment the chemist knows or believes he knows about seventy species of these elementary atoms.

"Not only," says Sir Henry E. Roscoe,* "has the "number of distinct well-established elementary bodies in-"creased from fifty-three in 1837 to seventy in 1887 (not "including the *twenty* or more new elements recently said "to have been discovered by Krüss and Nilson in certain "rare Scandinavian minerals), but the properties of these "elements have been studied, and are now known to us "with a degree of precision then undreamt of."

So we see by these words what a progressive science chemistry is, and it is probable the next generation or so will smile at the cramped, narrow ideas of the present chemist with his belief of some 70 elementary substances. But let it be, for a moment, 70, or 70 millions of elementary substances, the number does not affect the question, for the fact stands out in bold relief and is perfectly clear, namely: The

* President's Address, British Association, Manchester, 1887.

world, being built up of atoms, that pull or energy* which we call gravitation, *is the sum of the pull or attracting power of the atoms of which the world consists.* This is quite patent, for we cannot conceive a pull or attraction without an object pulling or attracting. The concept is easily grasped; no one can question the fact. Now, every atom has its specific attracting power; it is the pull of the atom, and this is an action to, or at a distance. It is altogether independent of any intervening material. This pull in the mass acts at enormous distances with objects in stellar space. There is no evidence to show it requires a medium as a vehicle. We cannot understand the "how" in the case; it is enough for us to know that there is this attracting power, and its knowledge is sufficient for the welfare of the human being. We cannot tell, therefore, how this property of matter exists or from whence it came, neither can we tell how certain objects have certain specific weights, colours, etc., nor, in a word, even, how it is that "we are."

69. We will make, therefore, a hard and fast line in our knowledge—that there is this specific pull, the property of each atom. Now, this pull or attracting power differs with each species of atoms or molecules. Hence we have the specific attracting power or pull of the hydrogen atom, of the oxygen atom, and so forth. This pull is always a

* "Energy is never found except in association with matter." Article "Matter," "Chambers' Encyclopædia," 1891.

constant; it radiates in all directions from the atom or molecule; its power spreads in space equally in all directions; as it is spread over a larger volume of space it becomes weaker, just in proportion to distance. The value of this pull in the mass is what is called by the physicist the "intensity of gravity," and the weakening of it by distance, from the source of the pull—the atoms or molecules—is expressed by the physicist as "the law of inverse squares."

70. So just and exacting is Nature in her dealings, that the addition of one atom only of such a light material as hydrogen will effect the attracting power of the earth as a whole; but who can measure such a factor? *

71. Each atom, and consequently each molecule, having its specific pull, it follows each species has its specific pull. Thus we obtain the factor called the density of the mass of a given species. The sum, therefore, of the pull of the atoms of which the earth is built is terrestrial gravitation. It follows that the pull of atoms or molecules *to* the surface of the solid and liquid portions of the earth (this being the habitat of man) must be the "weight" of those atoms or molecules.

72. The power of gravitation may be illustrated in the following way: Consider a rowing boat containing twenty-

* "Remember how small a force gravitation is. Ask any educated "man whether two pound-masses of lead attract each other, and he "will reply no. He is wrong, of course, but the force is exceedingly "small. Yet it is the aggregate attraction of trillions upon trillions of "atoms."—"Modern Views of Electricity," Prof. Oliver J. Lodge, 1892, p. 415.

six rowers, which we shall call *a* to *z*. Suppose *a* is a very powerful rower and *z* a very weak rower; and, further, suppose that there are gradations of powers from *a* the strongest to *z* the weakest. Then we shall have, in a very limited degree, a simile of the pull the earth has in its attractive pull or gravitation. For just as the movement of the boat is the result of the sum of the pull of the various rowers, strong or weak, so is the pull of the earth the pull of the individuals—the atoms, or molecules, of which the earth is composed—some species pulling or attracting strongly (illustration, platinum) and some weakly (illustration, hydrogen).

73. Consider the consequence of this action at a distance, this pull of the earth—gravitation. It will follow that inasmuch as the mass of the earth at any part is nearly a constant, the gravitation or the pull of the earth may be regarded as a constant. We say, nearly a constant, because the solid, the liquid, and the gaseous are ever interchanging. This is the more marked in the liquid than in other bodies. The constant evaporation of the fluid, its resolution into the gaseous* and its suspension in the gaseous—the air; the constant rejection by the gaseous, through the water gases becoming the liquid, and the deposition of the latter in the great reservoirs of the world—the oceans, in the phenomena we call rain,

* The condition of water as a true gas is not generally recognised. This condition will be shown further on.

rivers, &c., are instances of the real inconstant conditions of the earth's crust and atmosphere. So that the power of pull on the earth's surface, in the medium of the outer envelope of the earth—the air—is constantly slightly varying. But this variation is so slight that we may neglect it and call the pull of the earth at any fixed place upon the earth's surface a constant.

74. Now we have a factor to consider which we cannot neglect—centrifugal force. Everyone knows that if we attach a rather heavy object—say a weight—to an elastic string and whirl it round, the greater the speed, the greater the circle the weight makes as it tends to get from the centre; hence the word centrifugal.* The

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* The effect of atomic and molecular centrifugal force is generally illustrated by means of the following model (Fig. 11a).

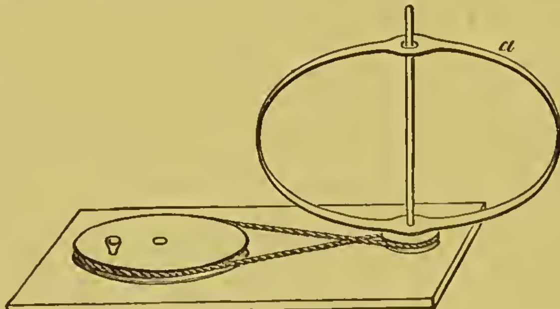

Fig. 11a.

The brass hoop *a* (which is thin and elastic) spreads out at its equatorial region, and becomes depressed at its axis, in proportion to the intensity of rotation. Now, what answers to the elastic band, in the illustration we have given above, or what prevents the atoms or molecules flying into space? Why, the individual attractive power of each atom or molecule to each other.

These reactions are beautifully illustrated by the following simple experiment (Fig. 11b). A glass receiver, having a glass tube of

object, whatever it may be, is built up of atoms. In like manner these masses of atoms are spun round by the rotation of the earth on its imaginary axis, tending to get away from the centre of the earth; and if the speed

small bore (*b*)—in fact, a funnel—is filled with water. The water is attracted by the mass of atoms and molecules of which the earth consists, and thereby falls into the glass receiver below. Notice that from the outflow of the receiver to the point *a*, molecular cohesion exists, and the stream of water molecules gets thinner and thinner to this point. Now the cohesion in part breaks down, and the water drops—drop by drop. The fall, however, is so fast that it is difficult for the eyes to trace the individual drops of water. While cohesion exists the mass of water molecules looks like a solid glass rod. This simple experiment is very instructive. How common is the experiment! Scarcely a screw-down water tap exists but the phenomenon has been seen by the careless observer, but how many of the millions of human beings have cared even to study such a familiar, beautiful and instructive object ?

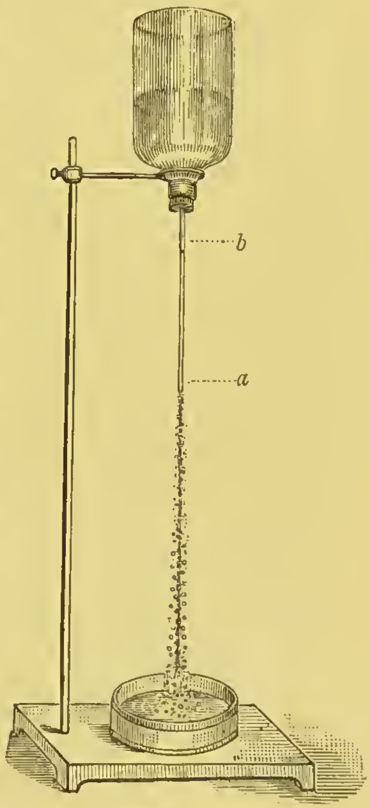

Fig. 11b.

If centrifugal force exceeds atomic or molecular attraction, the atoms or molecules fly off into space. This is illustrated thus: Attach shots by means of some plastic material, say wax, to the model (Fig. 11a) at the part where the greatest bulging takes place. The plastic material represents the cohesive power of the molecules of which the world is built; now whirl the model, and at a certain speed the shots will fly off into space. And so would our earth disintegrate and fly into space if its rotation were to exceed a certain intensity. It is estimated that if the earth were to rotate at a speed exceeding one rotation in three hours, it would fly to pieces.

of rotation were increased, the form of the earth would alter.

Let us consider the effects of these combined forces —the atomic pull tending to produce that contact between atoms and molecules we call cohesion, and the centrifugal force tending to force asunder the atoms or molecules—these combined forces would produce a hollow sphere, the section of which is shown in Fig. 11.

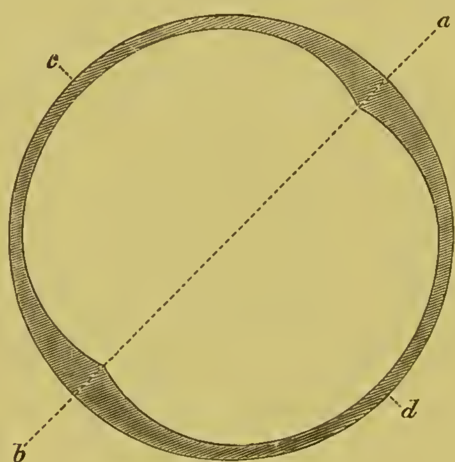

Fig. 11.

The illustration shows an ideal section of the earth; it exaggerates the fact, so that the idea may be the more readily grasped.*

* It is remarkable that since the above was written the following event has taken place. The quotation is from *The Times* newspaper, dated Tuesday, August 16th, 1892. *The British Association: a Retrospect.*—"It is admitted that the address of Professor Lapworth to the "Geological Section was the most suggestive and probably the most "original of all the addresses given at the meeting. Professor Lapworth "is recognised by the younger school of geologists as a leading spirit. "On the basis of solid investigations he builds what at first sight

Here *a b* shows the imaginary axis, and *c d* the equator. The shaded part shows the order of thickness of the so-called mass of the earth. The centrifugal force will cause the crust of the earth to be thinner at the

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"seems daring speculations, but which when carefully followed will be "seen to be carefully-drawn inferences. His address was a compre- "hensive survey of the great inequalities—the enormous bulges, with "their accompanying deep depressions—which characterise the surface "of the earth. He himself admitted that his address was as much "geographical as geological. His striking description of the great "folds of the earth's surface and their relation to each other might "have been given in Section E; but he went deep down and far back "in order that he might be able to account for the origin of these "folds. The subject chosen by Professor Lapworth for his address was "one of the widest that could be dealt with by a geologist, and it is "doubtful if it has ever been treated more philosophically or with a "more thorough knowledge of the various forces and materials with "which the science has to deal. No doubt some of the positions taken "up by Professor Lapworth will be assailed both by the older geologists "and by astronomical physicists; but, whether he is right or wrong in "all that he maintained and suggested, his address will certainly "inspire others to dive more and more deeply into the secrets of the "earth's crust. One of Professor Lapworth's concluding paragraphs is "worth quoting:—'We seem to be dealing, not with a globe, but with "'a globular shell composed of many layers. Is it not just possible "'that our earth is just such a hollow shell, or series of concentric "'shells, on the surface of which gravity is at a *maximum*, and in whose "'deepest interior gravity is practically non-existent? May this not "'be so, also, in the case of the sun, through whose spot-eddies we "'possibly look into its hollow interior? If so, perhaps our present "'nebulæ may also be the hollow shells formed of meteorites; on the "'surface of these shells the fiery spirals we see would be the swirls "'which answer to the many twisting crustal septa of the earth. "'Our comets, too, in this case, might be elongated ellipsoids, whose "'visible parts would be merely sheets of differential movement.' "This is bold writing, which may not commend itself entirely either to "the spectroscopist or the physicist."

equator, where its effect is the greatest, and thicker at the poles, where its effect is the least; but what must be the result in terms of weights? Why, bodies weigh heavier at the poles than at the equator because the vertical pull results from the pull of the greater number of atoms and molecules in section; the lesser pull at the equator results from the pull of the lesser number of atoms at the section. Bodies at the equator are $\frac{1}{289}$ lighter than at the poles, and bodies at the poles $\frac{1}{590}$ heavier than at the equator.* The result would be quite different if the world were solid, or solid and liquid combined, giving a mean of structure equal to a homogeneous solid mass. This would be the probable condition of the interior of the earth if it consisted wholly of a molten or liquid mass. We say the condition would be different because the dimensions from pole to pole is less than the dimensions of the equator. The equatorial diameter is 7,926·6 miles, while the polar diameter is 7,899·6 miles. Hence, if the attraction called

* "The intensity of gravity at the earth's surface is measured by "the acceleration of a body falling freely under its influence; it is "usually denoted by *g*. It is found, from pendulum experiments, to vary "slightly with the latitude, and also with the height above sea level of "the observing station. . . . A body apparently gains weight as "it is carried from the equator to higher latitudes. This is due to "two causes. First, owing to the ellipsoidal shape of the earth, "gravitational attraction at the poles is $\frac{1}{590}$ greater than at the "equator; (2) Owing to the 'centrifugal force' of the earth's "axial rotation, bodies at the equator are $\frac{1}{289}$ lighter than at the "poles, where this cause does not effect their weight."—Article "Gravitation," "Chambers' Encyclopædia," 1890.

gravitation were the attraction of mass (§ 76), and this is the mathematical notion, bodies should weigh heavier at the equator than at the poles. This is found not to be the fact. Newton's Law of Gravitation is thus expressed:

"Every particle of matter in the universe* attracts "every other particle with a force whose direction is that "of the straight line joining the two, and whose magnitude "is proportional directly as the product of their masses, "and inversely as the square of their mutual distance."

75. From the point of view we have presented this problem, it ceases to be a difficult concept to grasp. From the metaphysical and mathematical point of view the problem cannot be solved; hence, in this case, the science of mathematics † absolutely fails, and the mathematician candidly acknowledges his failure.

76. It is very curious and very instructive to notice how the specialists flounder about in the confusion with which they have surrounded themselves. Let us see what Clerk Maxwell says about weight, and we must take it, since there is no correction, also what Lord Raleigh says:—

* This law includes, of course, every atom and molecule of which the earth is composed.

† "Mathematics may be compared to a mill of exquisite workman- "ship, which grinds you stuff of any degree of fineness; but, never- "theless, what you get out depends upon what you put in; and as the "grandest mill in the world will not extract wheat-flour from peascods, "so pages of formulæ will not get a definite result out of loose data." —T. H. Huxley, from "Lay Sermons, Addresses, and Reviews," 1893, p. 216.

"The weight, strictly so called—that is, the tendency "of this body to move downwards—is not invariable, for "it depends on the part of the world where it is placed, "its weight being greater at the poles than at the equator, "and greater at the level of the sea than at the top of a "mountain. What is really invariable is the quantity of "matter in the body, or what is called in scientific lan-"guage the mass of the body,* and even in commercial "transactions what is generally aimed at in weighing "goods is to estimate the quantity of matter,† and not to "determine the force with which they tend downwards." . . . "As a great deal of confusion prevails on this "subject in ordinary language, and still greater confusion "has been introduced into books on mechanics ‡ by the "notion that a pound is a certain force, instead of being, "as we have seen, a certain piece of platinum, or a piece "of any other kind of matter equal in mass to the piece of "platinum, I have thought it worth while to spend some "time in defining accurately what is meant by a pound "and a kilogramme." §

So then, according to this statement by Maxwell and Lord Raleigh, weight is *not a force*.

* The idea here held appears to be: all atoms have the same weight, and are of the same volume. Hence a cubic inch of water has a certain number (unknown) of atoms, whilst a cubic inch of platinum contains about 21 times *more* atoms, of the same weight, than the water does, its density being 21·50. Now this concept in gases is absolutely contradicted by the law of Avogadro (§ 78). Both notions cannot be true (§ 38).

† This implies: the quantity or number of atoms.

‡ Does not this expression show the necessity of harmonising departmental views?

§ "Theory of Heat," by J. Clerk Maxwell, M.A., etc., corrected by Lord Raleigh (10th edition), 1891, p. 80.

77. Now let us go only three pages further on (p. 83) and note the confusion such ideas lead to :—

" It was only after the measurements of forces made by "persons in different parts of the world had to be compared that it was found that the weight of a pound or "a gramme is different in different places, and depends "on the intensity of gravitation or the attraction of the "earth ;* so that for purposes of accurate comparison

* This gives the notion that the attraction of the earth is the sole factor. It is very curious how deep-seated the idea is that gravitation—*i.e.*, the attraction of the atoms and molecules of the mass of the earth—is the *sole* factor in weight. This arises from the well-known experiments of Galileo, which imports: that all bodies fall at the same rate, except for the disturbing effect of the resistance of the air. In other words, bodies having different densities, but of the *same forms and dimensions*, must when falling to the earth travel through space at an equal velocity. Is this statement true ? We think not, from the following considerations : Take two plumb weights of equal dimensions and the same shape—one light, of wood ; the other heavy, of lead—the former weighing say 140 grains, the latter say 2,700 grains. Attach each by means of a string to fixed points from a fixed horizontal bar, at a certain distance from each other, say six inches. Let the strings be equal in length, so that the plumbs are exactly equal distance from the rigid horizontal bar. Now start these pendulums at a definite angle, so that they both are set swinging at the same instant and from the same horizontal plane. What is the result ? They oscillate with different velocities, proving that there is a difference of attraction to the earth's surface. The opposite is constantly, but very crudely, shown experimentally; practically the same way as Galileo made the experiment from the Tower of Pisa. But in considering the results obtained, allowance must be made for two facts: 1st, the attraction of the atoms and molecules of which the earth consists is so overwhelming, compared to the attraction of the molecules which form the mass of the falling weights, so that when the weights are allowed to fall freely, the difference of time in falling a given distance is so minute as to be

"all forces must be reduced to absolute or dynamical "measure." . . . "We shall distinguish the measure "by comparison with weight as the *gravitation* measure "of force." Hence weight *is a force.*

So, then, here are two absolutely opposite ideas! Weight is *not* a force. Weight *is* a force. Both cannot be true.

78. But these contradictory and repulsive notions become still more apparent when we consider one of the great fundamental laws of the chemist. We mean the so-called Avogadro's law. We shall not now use our own words; we prefer to use the expression of another thinking mind, and thus bring collateral evidence with ours.

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inappreciable; and the 2nd difficulty is our sense of sight is not delicate enough to see when the heavier object touches the ground first. This notion is often proved by what is known as the guinea and feather experiments. A coin and a feather are lodged in the upper part of a high receiver upon an air pump. At first the two objects are allowed to fall simultaneously from the top of the receiver to the plate of the air pump in air at ordinary pressure, and of course the coin falls to the ground first and the feather shortly afterwards. Then the receiver is exhausted—the air becomes rarified—that is all, and what does rarification mean? *Air still exists in the receiver.* What happens? The coin and feather *appear* to touch the plate of the receiver at the same instant of time. Now, we know in this experiment we cannot obtain a perfect vacuum; hence, if air be the resisting factor in the first experiment, there must be a resisting factor in the second experiment, but we cannot appreciate its effects. For about two and a half centuries has this notion been preached, and yet such a simple experiment as we have shown can say—does say—the teaching is not truth.

Stallo says: "Now, while the absolute equality of the "primordial units of mass is thus an essential part of the "very foundations of the mechanical theory, the whole "modern science of chemistry is based upon a principle "directly subversive of it—a principle of which it has "recently been said that 'it holds the same place in chem-"'istry that the law of gravitation does in astronomy.'* "This principle is known as the law of Avogadro or Ampère. "It imports that equal volumes of all substances, when "in the gaseous state and under like conditions of pressure "and temperature, contain the same number of molecules "—whence it follows that the weights of the molecules are "proportional to the specific gravities of the gases; that, "therefore, these being different, the weights of the mole-"cules are different also; and, inasmuch as the molecules "of certain elementary substances are monatomic (*i.e.*, con-"sist of but one atom each), while the molecules of various "other substances contain the same number of atoms, that "the ultimate atoms of such substances are of different "weights." †

* "The New Chemistry," by J. P. Cooke, LL.D. (10th edition), 1892, p. 5.

† "The Concepts and Theories of Modern Physics," by J. B. Stallo (2nd edition), p. 33. The layman will, perhaps, better understand the case if we represent it thus: Overwhelming evidence is given to the chemist that under like conditions of temperature and pressure the same volumes of different gases contain the same number of molecules. Thus, suppose a cubic inch of oxygen gas contains a million of oxygen molecules, a cubic inch of hydrogen gas will also contain a million hydrogen molecules. Now the cubic inch of oxygen weighs 16 times as heavy as the cubic inch of hydrogen. Hence each molecule of oxygen must weigh 16 times as heavy as a molecule of hydrogen. But equally overwhelming evidence is given that the oxygen molecule consists of two atoms, also the hydrogen molecule

79. To sum up, the only concepts which can explain the facts are these: Matter is built up of atoms—there are various species of atoms, the number of species are unknown — the individuals of each and the same species, have the same potentialities or inherent powers; amongst those powers, the power of pull or attraction is a specific power belonging to each individual atom; or, otherwise expressed, all individual atoms of the same species have the same intensity of attraction or pull. Different species have different intensities of pull. This intensity decreases the greater the distance from the atom in an order of inverse squares. Therefore each species of atom (and consequently every molecule) has its specific intensity of pull or attraction. The sum of the pull of the atoms of which the solid and liquid mass of the earth consists is the *intensity of gravitation* on the surface of the solid and liquid contents of the earth. The sum of the pull of a mass of atoms *to* the earth when held suspended as in a balance is the *weight* of that mass. When we compare various masses as in a balance, we get the ratio of the weight of the masses of atoms or molecules weighed. *This pull of gases or weight of gases on the earth's surface produces*

consists of two atoms (§ 42). Hence the oxygen atom is 16 times heavier than the hydrogen atom. Now the physicists who build their evidence upon the mechanical theory, which we believe is now seen to be erroneous, while ignoring the overwhelming evidence given to the chemist, simply assert that the deduction of the chemist is *not true*. Here is a simple and fundamentally important issue. Both specialists cannot be right. This much is certain.

the pressure of the air. These ideas are simple and easily grasped.

We shall see how this important factor of atomic and molecular pull or attraction explains many of the reactions called Heat or Cold.

PART IV.

STATEMENT OF THE CASE.

THE LAWS RELATING TO MATTER.

PART IV.

ON THE LAWS RELATING TO MATTER.

"*All scientific research, in order to be undertaken and fol-*"
"*lowed up with success, should have, as point of departure,*"
"*a preconceived idea, an hypothesis which we must seek to*"
"*verify by experiment*" (Louis Pasteur).*

"*To tell us that every species of things is endowed with*"
"*an occult specific quality by which it acts and produces manifest*"
"*effects is to tell us nothing. But to derive two or three general*"
"*principles of motion* FROM PHENOMENA *and afterward to*"
"*tell us how the properties and actions of all corporeal things*"
"*follow from these manifest principles would be a very great*"
"*step in philosophy, though the causes of those principles were*"
"*not yet discovered*" (Newton).†

"*The secret of all those who make discoveries is that they*"
"*regard nothing as impossible*" (Liebig).‡

80. The first of these quotations points to the order of thought and mode of procedure adopted in this work. There are two modes of scientific enquiry. One to get together a host of facts, and we have now got an enormous quantity of these facts, all obtained in a heterogeneous manner. The other is to follow the mode adopted by

* "Louis Pasteur: his Life and Labours," 1885, p. 140.

† From Stallo's "Concepts and Theories of Modern Physics," 1885, p. 110.

‡ *Idem*, p. 140.

Louis Pasteur, viz.: 'to obtain preconceived and clear ideas (such notions are the very vivifying factors in scientific progress) and then to prove them by experiments.

The second quotation shows the scope of our work, and the third contains a caution to the dogmatic mind given by a high authority. In such a work as this is, this caution of Liebig's should be well kept in view.

81. We shall proceed by formulating our preconceived ideas,* and in the next part prove these concepts experimentally. Following then our mode of procedure (§ 36) this chapter may be called—

THE STATEMENT OF THE CASE.

1. All matter is built up of *atoms* having specific attracting powers, which occupy space, and which, under fixed conditions, combine to form *molecules*. The number of species of these atoms is unknown. There is, probably, an enormous number.

* The words "preconceived ideas" should not be regarded by the reader as ideas which have suddenly arisen in the mind; they are introduced in this form so that the reader may easily obtain the scope of this important problem. The ideas have been the result of careful investigation. Only one concept, as far as the author is concerned, may be said to be a preconceived idea, namely: that the ultimate particle, recognised by the chemist and physicist, is not a constant in dimension. All the other factors introduced in this chapter are deductions arrived at from this initial concept by careful reasoning and testing by experiment. So they are not "preconceived ideas" as far as the author is concerned; they only become so to the reader for the object named above.

2. "Heat" and "Electricity" are words or terms expressing the reactions caused by the absorption and flow of an *incompressible* fluid, passing *into and through* (§ 110) the atom or molecule. This fluid we will call "*ether*"; it is, we shall presently demonstrate, easy to be seen (§ 91). Most likely it is a compound fluid.

3. When ether is uninfluenced by external forces, it rises from the surface of the earth or *antigravitates*; and when atoms or molecules absorb this fluid, they increase in volume in the ratio to the quantity of this fluid absorbed, and they become in that ratio also specifically lighter. Therefore atoms and molecules are not constant in dimensions.

4. The difference in dimensions of atoms or molecules by reason of the quantity of ether held by them at a given moment is what is called the "*temperature*" of the atom or molecule (§ 107).

5. When the increase of the flow of ether *through* the atom or molecule is slow, the object simply and slowly increases in dimensions; but when the flow becomes fast, then the atom or molecule both increases in dimensions and *vibrates*. The vibrations consist of a rhythmical but small and very quick alternate contraction and expansion of the atom or molecule *per se*. The flow of ether through the atom or molecule is called "*radiation*," and the passing on this fluid *by* the atom or molecule is called "*conduction*."

6. This vibration commences at different volumes of the atom or molecule (different temperatures), and at different internal pressures of the fluid ether, *according to the special species of atom or molecule which passes on this fluid,* external pressure is also an important factor (§ 79). The specific power of each species of atom or molecule to pass on this fluid produces the reaction we call "*specific conductivity.*" Internal pressure *in* the atom or molecule, or that pressure caused by the intensity of the flow of ether, we will call "*strain.*" External pressure, or the pressure arising from weight or gravitation or any other pressure, we will call "*stress.*" There is also a second "*stress,*" arising from the inherent power of the atom or molecule, which tends to contract *per se* (§ 114). When "strain" and "stress" are equal, being opposite, "temperature" is constant.

7. In gases and liquids, when this reaction of vibration exists, it produces an inter-atomic or inter-molecular vibration of impact and recoil, and great molecular motion may ensue—"*ebullition.*" It always goes on faster and faster, increasing as the flow of ether or the conductivity becomes greater.

8. Atoms and molecules being thus capable of expansion and contraction *per se,* when at certain dimensions or volumes (*temperature*) resulting from the internal pressure of the ether (*strain*), are in a condition which

permits them to get one into the other, and thus absorb one another, and this process of *overwrapping* is what is termed by the chemist "*bonding or chemical combination.*" Hence at a certain "*strain,*" producing "*specific temperature*" (*i.e.*, certain dimensions of the atom and molecule), chemical combination takes place, as also does the inverse process, decomposition. It will follow, without the absorption of ether, or without the existence of ether, no chemical reaction can take place (§ 1).

9. Nature tends to avoid free ether, that is ether existing *between* the atom or molecule: hence atoms or molecules under external pressure (gravitation or otherwise) tend always to be in contact, as marbles do in a vessel. This is the consequence of the attractive powers of the atom or molecule. (*See* Part III., Gravitation). The exception is explained in § 136.

10. When chemical combination takes place—that is, when atoms or molecules overwrap each other—and *vice versa* (chemical decomposition), the reaction is generally attended with noise. We call it sound. This sound is hardly or not appeciable by the human ear when the combination is slow—"*combustion*"; but it is readily heard when the combination is quick and considerable in quantity—"*explosion.*" Hence combustion and explosion are but terms showing the difference of degree of chemical reaction, resulting from the intensity and rapidity of the flow of ether.

11. Atoms and molecules assume several forms. At a certain low temperature they constitute the solid; they may be angular—"*crystalline*"; but as the temperature increases they become spheroidal or spherical, and at a certain temperature they cease to cohere or adhere; hence they become fluids. It is possible that at a certain decrease in temperature, *i.e.*, decrease in volume, the surface of the atom or molecule becomes creased somewhat in the following manner:—

A  B

Fig. 9a.

Where A is the surface of one atom or molecule and B the other when the contraction continues, the irregularities of A dovetail themselves into B, and tighten as they contract: this is in solids "*cohesion*" or "*adhesion*." Hence the colder solids are (providing they are homogeneous), the firmer is the cohesion or adhesion.* The rate at which they are allowed to cool is a factor affecting the result.

12. When the atom or molecule in the liquid condition increases in temperature, or to a certain volume, under a given intensity of flow of ether (strain), it *suddenly* absorbs a considerable quantity of ether and becomes a vesicle of ether: this is the gaseous condition of the atom or molecule. This operation can be seen by means of the microscope (§ 186).

* This fact has been recently proved by Prof. Dewar (Friday Evening Discourse, Royal Institution, January 19th, 1894).

13. Atoms or molecules passing from the solid to the gaseous form generally pass through the liquid condition. The differentiation may, however, be so short in time as not to be appreciable.

14. The temperature at which solids become liquids, or liquids become gaseous, entirely depends upon the inherent power ("*energy*") of the special species of atoms or molecules reacting under the influence of the fluid ether. Hence every species of atom or molecule has its specific solidifying, liquefying, or gaseous point or moment.

15. Atoms and molecules, in their liquid and gaseous forms, are spheres or spheroidal bodies, and have the motions of translation from one part of space to another, a motion of rotation *per se*, a motion of expansion and contraction *per se*, which may differentiate into a motion of vibration of such intensity as to produce light. This vibration produces the vibration of impact and recoil (*see* sub-clauses *5* to *7*, also § 114).

16. Vapours are atoms or molecules in the gaseous condition super-saturated with ether. Hence the dimensions (or temperature) of these objects are abnormally large; they speedily loose or radiate the excess of ether, and thereby become reduced in dimensions, and assume the gaseous, liquid, or solid condition. A very beautiful illustration of the vaporous condition of the molecule is shown in steam, and it

is this increase in dimensions of the water molecule by the absorption of ether under a considerable internal pressure of ether (strain) which moves the piston in the cylinder of the steam engine. We shall see that this molecule expands to such great dimensions, in air, that it becomes visible even to the unaided vision (§ 174).

17. Hence all vapours and gases are elastic vesicles of ether. In consequence of the internal pressure (strain) exceeding the external pressure (stress), as in the condition of the atmosphere, they are always spherical or spheroidal, or tend to these conditions of form.

18. When external pressure (stress), atmospheric or otherwise, is applied to atoms or molecules in the gaseous or vaporous condition, the ether is mechanically pressed out of the atoms or molecules: this outflow of ether is forced on the atoms or molecules in contact with those giving out ether. Hence the pressure of gases in a cylinder makes the cylinder warm—*i.e.*, the molecules of which the cylinder is composed increase in temperature; they are in this condition super-saturated with ether.

19. Ether being an incompressible fluid, and all other atomic and molecular matter being capable of expansion, contraction, and conduction of ether, it follows there must be a power of the fluid, ether, to pass *from* and *through* atoms and molecules. When this flow of ether takes place without in-

creasing or decreasing the dimensions of the atom or molecule, it assumes the condition of simple radiation; but when it passes through the atom and molecule so fast or with great intensity (strain) as to produce expansion, then the atom or molecule both increases in temperature and radiates ether, and we call such material "*heated.*" There are therefore two reactions in the latter case. When the atom or molecule becomes "*chilled*" or "*cold,*" the process is inverse.

20. Ether is ever present. It, like atomic matter, cannot be created or destroyed. It is always in motion. Its small radiations are generally unrecognised. It flows in currents and streams like any other fluid. (§ 195.)

21. It will follow from the foregoing, whenever chemical reaction takes place, so that the sum of the volumes of the atoms or molecules arising from the reaction produce an increase of volume, there is an absorption of ether by the molecule, or a "soaking in," causing a radiation of ether *to* the molecule; and whenever the reactions produce a diminution of volume,* there is an exudation or a "soaking out,"

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* This does not always seem the case as seen in the mass, because when atoms or molecules alter from the spherical form to the angular, if they so arrange themselves as to increase the volume of the mass, then at the moment of the alteration in shape the temperature of the molecule seems to increase and not decrease. Instance crystallization (§ 180).

producing an evolution of ether—radiation. When there is an evolution of ether resulting from chemical combination, it is quickly absorbed by surrounding atoms or molecules, but it remains a very short time as inter-molecular or free ether (§ 136).

22. Under ordinary conditions ether is like most gases, invisible; or, to use the term proposed by Dr. Tyndall, both ether and gases generally are "optically empty." We shall see the conditions in which gases and ether are made visible. If ether and gases were not "optically empty" objects in stellar space could not be seen.

23. When atoms and molecules vibrate at a certain intensity (*see* sub-clauses *5* to *7*) they become luminous. Hence, under the influence of a certain intensity of flow of ether, matter generally becomes white or red hot. Also in the so-called vacuum tubes gases become luminous.

24. To sum up these factors. We recognise three different relative conditions of the molecule:—1st, When it is saturated with ether, we then get an equation (illustration, when the thermometer gives the temperature of surrounding media); 2nd, A condition of super-saturation of ether; and 3rd, A condition of under-saturation. All these conditions are illustrated by the thermometer. Matter without ether, or with a minimum of ether, as it were, sleeps. Let us

consider a globe or world in this condition: there would be neither atomic nor molecular motion. Given a small addition of the fluid ether to this world, what takes place? That which receives this fluid would absorb it first, but it would speedily spread or diffuse (radiate) amongst the atoms and molecules *pro rata* to the capacity of the various species of atoms and molecules to absorb it, and they thus increase in dimensions—*i.e.*, temperature. Let still more ether be given, then the various degrees of conductivity belonging to each species of atoms and molecules will be more marked. And thus, according to the increase of the amount of this ether in and on the world, become active, those potentialities we call energy, motion or force and *life*. Energy, therefore, is very complex. Thus the power of atomic and molecular attraction is energy, so is the power of atoms and molecules to combine or to decompose, energy, as also is their power to expand and contract *per se*. These are all functions of the atom and molecule, and when these functions are active we may call the operation, if we like, kinetic energy—doing work.

PART V.

ON HEAT.

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I.

82. Clerk Maxwell, in his work "Theory of Heat," expresses the idea of the flow of a fluid in the following manner:

"Heat, therefore, may pass out of one body into "another just as water may be poured from one vessel "into another, and it may be retained in a body for any "time just as water may be kept in a vessel." * . . . "We find the cooling of a hot body and the heating "of a cold body happening simultaneously as parts of "the same phenomenon, and we describe this pheno- "menon as the passage of heat from the hot body "to the cold one. Heat, then, is something which may "be transferred from one body to another, so as to "diminish the quantity of heat in the first and "increase that in the second by the same amount." † . . . "Heat passes from one body into another "through an intervening substance, as from a vessel of "water through the glass bulb of a thermometer into "the mercury inside the bulb. This process, by which

* "Theory of Heat," by J. Clerk Maxwell, M.A. (10th edition), 1891. Revised by Lord Rayleigh, Sec. R.S., p. 7.

† *Idem*, p. 6.

"heat passes from hotter to colder parts of a body, "is called the conduction of heat." ‡

Substitute the word "Ether" for "Heat" and call the reaction of Ether with the atom or molecule, "Heat," then Maxwell's expressions become perfect.

83. A great part of Maxwell's "Theory of Heat" is expressed in the terms that Heat is a fluid. It is only when Maxwell brings into consideration mathematical concepts—which are ideas, by the way, he frankly acknowledges he does not understand (§ 17)—that he changes front and defines this fluid and its reaction on the atom and the molecule as that of the motion, *and motion only*, of atoms or molecules. In other words, so rigid and exact are the phenomena, that when Maxwell attempts to explain experiments and phenomena he is absolutely driven to express the reactions in the terms that Heat is a fluid. Although Maxwell maintains that Heat is only molecular motion, he has such grave doubts of this deduction that he, in his concluding chapters devoted to the question: "Is Heat Motion?" states:

"The evidence for a state of motion, the velocity "of which must far surpass that of a railway train, "existing in bodies which we can place under the "strongest microscope, and in which we can detect "nothing but the most perfect repose, must be of a

‡ *Idem*, p. 11.

"very cogent nature before we can admit that heat is "essentially motion." *

84. We now proceed to see the fluid "Ether." We must keep in view the fact: our power of sight can only be exercised by means of contrast. If all objects were black, and there were no light or shade, no objects would be visible. We must therefore seek a mode of contrast in order to see this ether, because it, like the gases of the atmosphere, is, under ordinary conditions, invisible to our sense of sight.

85. We shall employ the following apparatus for the purpose of seeing this fluid and for several other experiments in order to solve these great problems. From what we have seen, we have no doubt this apparatus, in the future, will be of great value as an instrument of investigation, as it makes the otherwise unseen objects and their motions visible to our eyesight.

A (Fig. 12) is a box 18 inches long, 7 inches broad, and 9 inches deep, raised from the table 8 inches. The object of raising it is, that apparatus may be brought beneath the box. The lid *g* slides in grooves. The front of the box is glass, and the two ends *F F′* are of glass. The lid, back and bottom are of wood; they are perforated with holes $\frac{3}{4}$ inch in diameter. The holes

* "Theory of Heat," by J. Clerk Maxwell (10th edition), 1891, p. 309.

a, *a′*, *b*, *c*, *d*, *e*, *f*, *i* are plugged with corks. We use those made of india-rubber. The holes *a a′* should be exactly opposite to each other. The cork *i* is perforated, and there is inserted through it a piece of bent glass tubing. The whole of the interior of the box except the glass is made dead black. We shall call this apparatus the *Analyser*. It will not be necessary to draw this box

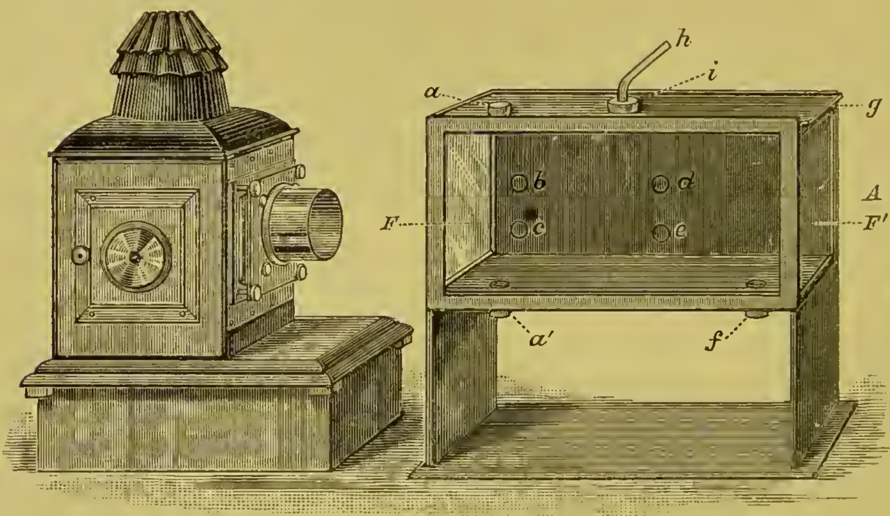

Fig. 12.

again, so our illustrations will only show sections of the box. The complementary piece of apparatus is the oxy-hydrogen lantern, or, better, the electric light lantern, using the condenser only. Practically for all the experiments, save one, the former lantern will do. The lantern is arranged so as to throw a powerful beam of light through the box entering at one end *F*, and passing through the other *F′*. Of course the apparatus is used in a dark room.

86. Having ignited the gases in the lantern, the first thing to do is to fill the box with fine motes, and this is most easily done by means of tobacco smoke, blowing the smoke from the mouth through the tube *h*. Any smoke will do—say, smoke from smouldering brown paper—but tobacco smoke is easiet to work with. It is well to observe the beautiful reactions which take place during the time the box is being filled, but notably we should observe this: Immediately after the mouth leaves the tube there falls from the tube a stream of white smoke; it often looks like a solid white rod. Out of the side of this smoke spring small vortex rings. They are very beautiful and very instructive, because if we let coloured fluid drop into a colourless fluid—for instance, a fine stream of ink very gently falling into clear water—we have exactly the same phenomenon. *See* Fig. 12a. This is a piece of evidence tending to demonstrate that gaseous objects are relatively placed to each other and have the same motions, as liquid objects.

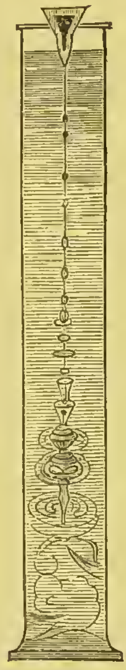

Fig. 12a.

(From "Stanley's Researches into the Properties and Motions of Fluids," 1881, p. 265.)

87. Before the box—the Analyser, was charged with smoke, the light passing through it was hardly visible, only the few motes existing in the air (as we see in the sunbeam) were illuminated. This arose from the fact that the gaseous molecules of which the air

consists are "optically empty"*—*i.e.*, invisible to our eyesight.

We have now sufficiently charged the box with motes. It is as well not to too highly charge the air with them, as if this is so done the best effects are not obtained. After a little time the motes become evenly distributed in the box. The box contains a fog. When it is charged with these motes and they are illuminated with the light, they form a brilliantly illuminated cone or beam of light. We must keep in mind the fact, that the gases are not illuminated—they are invisible—the motes only are seen in this beam of light. The experiment is made much more beautiful by placing between the lantern and the Analyser a convex lens so as to concentrate the light to a focus. But we must remark another thing, and a very important thing it is to observe. When we concentrate the beam of light by means of the convex lens, where the rays meet, that is where the light is most intense, the individual motes can be distinctly seen; and we must particularly notice they do not touch each other, and they are at a fairly even distance away from each other. We shall presently look at these remarkable objects under the microscope (§ 125).

88. Well now, every one knows, air is invisible. We cannot see air in air under ordinary conditions. If air

* This is the term given by Dr. Tyndall. See "Dust and Disease" Discourse, delivered before the Royal Institution of Great Britain, January 21, 1870.

were visible, we could not see objects in space, such as the moon or stellar bodies; it would act like a perpetual cloud. But we can see air in water. Take a tumbler of water and put a glass tube in the water, press air through the tube, then we *see* the air rising as a quantity of *air bubbles*, through the water. If our habitat were in water, as it is with the fish, water would be an invisible fluid, whilst air rising thus would be just as really a visible object to us, as water is a real visible object to us in our conditions of existence.

89. In this box, however, we are able to see air in air, as we can see water in air. It is as well to commence our experiments with this one, because it educates the mind for the further experiments. For this experiment, we use one of those india-rubber balloons commonly sold in the streets of London. It is a toy, but in our hands it becomes a useful scientific instrument. We attach to it a small stopcock, *b* (Fig. 13). We filter some air through cotton-wool* to remove motes. By means of a force pump,† we press the filtered air into the balloon *c*, which of course expands, and we thus collect under pressure nearly a cubic foot of filtered air *c*. We then turn off the stop-cock. We connect this with a piece of india-rubber tubing *d*, and at the other end

* It is not necessary to filter the air to get the effect, but the results are slightly better when the air is filtered.

† The force pump used is illustrated in Fig. 58.

with a piece of glass tubing *e* passing through a cork *f*. The following diagram will explain the complete apparatus :—

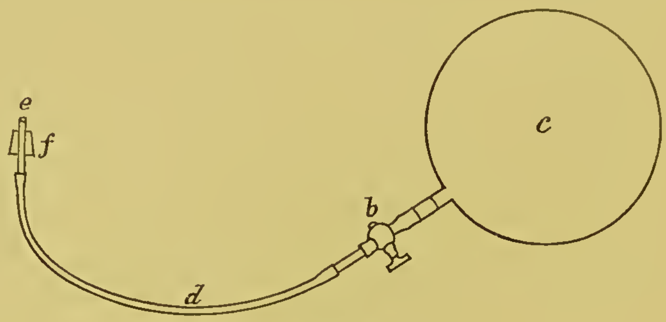

Fig. 13.

We now take out the corks *a a′* (Fig. 12) from the Analyser and insert the cork *f* (Fig. 13) in the place of the cork *a′*. We turn on the stop-cock *b* a very little and very carefully. The balloon contracts and pushes the filtered air into the box. The air from the balloon rises up between the air charged with illuminated motes, and thus the air which does not contain motes displaces and rises "optically empty" between the air charged with illuminated motes. In this condition it looks absolutely black, as it rises between and separates the air which is charged with the brilliantly illuminated motes. This "optically empty" air looks like a solid black rod pushed through the bottom of the box; it appears quite still, there seems no motion. The illustration (Fig. 14) represents the appearance of the reaction :—

There cannot possibly be a mistake in this experiment. We not only *see* the air rising in the box, but

we see the loss of air by the contracting of the india-rubber balloon.

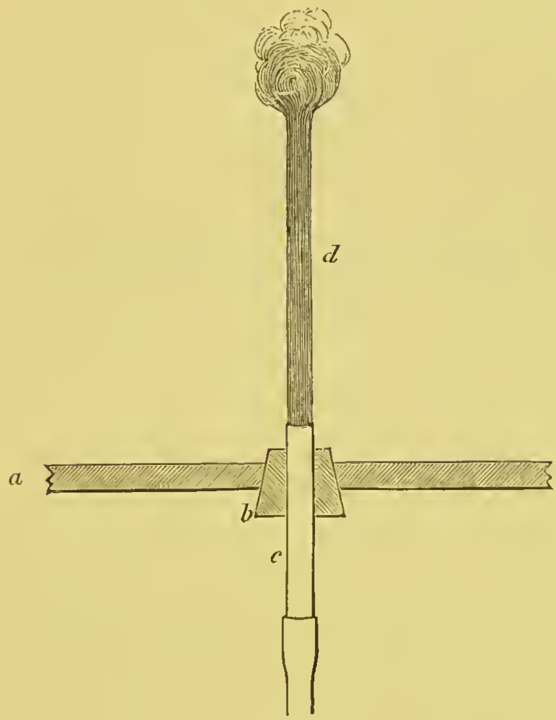

Fig. 14.

a the bottom of the Analyser (Fig. 12) from which the cork *a'* has been removed; *c* glass tube, with cork *b*, through which the filtered air *d* is passing.

90. Now we turn on the stop-cock further and all is changed. Instead of the air passing up like a solid carbon rod, it rushes out of the tube just like a jet of steam, only it looks like black steam. The following illustration represents the reaction. All sharp definition is now lost, and the black steam-like air, mixes with the air charged with motes. (Fig. 14a.)

Thus we see air in air, as we can see water in air. These reactions should be firmly impressed on our minds, and we must further observe the transition between

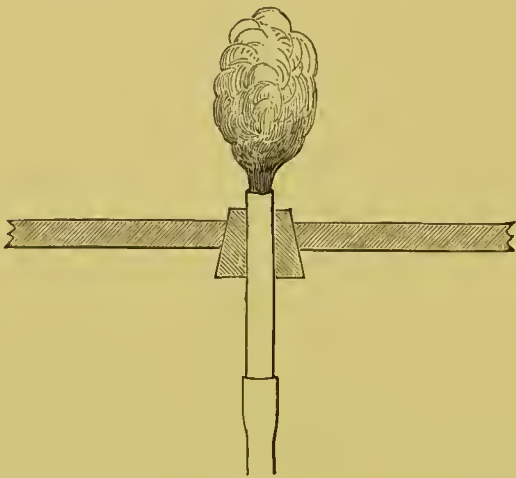

Fig. 14a.

the apparently black rod and black steam is one of degree in the ratio of velocity through the increased pressure by turning on the tap.

91. We reinstate the corks in the Analyser and let the air get to rest, keeping it charged with motes.

Now we take a glass rod, sufficiently long to reach nearly across from back to front of the Analyser. The rod passes through a cork thus (Fig. 15):

Fig. 15.

We take out the cork *c* or *e*, at the back of the Analyser (Fig. 12). We dip the rod into free ether—that is, as we

shall presently show (§ 136), ether existing free (§ 81—*21*) and between the gaseous molecules, and thus separating them. We do this by putting the rod into flame—incandescent molecules, for such is flame. The glass rod absorbs the ether, and a quantity of the ether adheres to the side of the rod. We pass the rod through the hole *c* or *e*, and then look *along* the rod through the glass front. Here is, indeed, a beautiful and surprising object. We see the fluid ether surrounding the rod, exuding out of the rod and parting the air molecules charged with illuminated motes. *This fluid rises from the rod, it antigravitates.* If we look at the rod slightly obliquely, we can see the fluid surrounding the whole length of the rod, and rising from it. Just as the air parted the mote-laden air in the previous experiment, so does the ether part the air in this experiment. When the rod is very hot, the ether is given off in considerable quantity, and the fluid so disturbs the mote-laden air that the stream of ether is not well defined, just as was the case in the air passing into the mote-laden air (Fig. 14a) under greater pressure. When the rod gets a little cooled, this fluid is given off in the most clear and well-defined manner, as was the case in the ascending air at a low pressure in the previous experiment (Fig. 14). Let us explain the experiment in another way. Suppose, instead of immersing the rod in ether, we had immersed it in some viscid substance, say glycerine, and we then held the rod perfectly horizontally, what would take place? Why, the glycerine would adhere to the

rod and surround it like a coat, and below the rod the glycerine would tend to fall in a stream along the whole length of the rod. This is illustrated in section below (Fig. 16).

Now the ether as seen in our experiment, instead of falling to the earth as the glycerine does, ascends from the earth as shown in section Fig. 17. Fig. 18 shows the view as seen obliquely. There is, moreover,

Fig. 16.

Fig. 17.

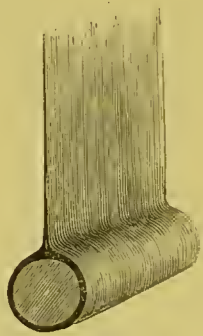

Fig. 18.

this other difference: In the case of the glycerine it only surrounds and falls from the rod, while in the case of the antigravitating ether it adheres to, rises from, and *exudes out of* the rod. Why do we know this? Because the rod decreases in dimensions, as it loses the fluid ether.

There is another way of showing this remarkable experiment. Heat the rod as before (*i.e.*, charge it with ether), take out the cork a' from the Analyser (Fig. 12) and insert the rod vertically, then notice the stream of

ether coming off the top of the rod, just the same as the gases do from off the tip of the finger (§ 141).

These beautiful and important experiments were first crudely noticed by Dr. Tyndall. His explanation was not tenable. Professor Lodge and Mr. Aitken have studied this black material, as has also Lord Rayleigh. No good explanation of the phenomenon has heretofore been offered.

Professor Lodge was particular to note one important fact, the illuminated motes are never seen to enter this black-like fluid. Why is this? Because the fluid ether is an incompressible fluid pushing its way through the mote-laden air and parting it just as we saw the air free from motes displaced and parted the air with motes. In both cases the reactions are the same.

92. We may call this fluid "Ether," smaller or finer atomic matter* than the atomic or molecular matter recognized by the chemist and the physicist.

93. Is there attraction between the particles of which ether is composed? We think not. We think the distinct appearance of this fluid arises from the

* Even the physicist is approaching this concept: "Another "result of this investigation is of considerable importance in relation "to certain theories which assume the existence of æthers or rare "media consisting of molecules very much smaller than those of "ordinary gases."—"Maxwell's Scientific Papers," Cambridge University Press, 1890, vol. ii., p. 457. (Article "Atom," from the "Ency-"clopædia Britannica.")

pressure of the air atoms upon it, because Professor Lodge states that "the coat enlarges with diminished "pressure and narrows when the pressure is increased."* This question wants to be carefully studied.

II.

94. Our next step in deductive investigation is to ascertain the reaction of the air molecules † with this fluid, for there is more taking place than their displacement by the ether. In order to understand the reaction we must get definite ideas of the gaseous molecule.

95. It will be convenient to consider a well-known form of molecule, the water molecule, and then consider the results of its decomposition and thus get clear fundamental ideas regarding the structure of atoms and molecules, and, having obtained these fundamental ideas, we can examine the air molecules in the Analyser.

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* Discourse given at the Royal Institution of Great Britain, May 28th, 1886.

† Air consists of, principally, two classes of elementary matter, in the proportion (roughly) of 4 parts of nitrogen and 1 part of oxygen. Now, the nitrogen entity is regarded by the chemist as a molecule consisting of 2 atoms of nitrogen, and the oxygen entity is also a molecule consisting of 2 atoms of oxygen. So the principal objects of which the air consists are molecules. When therefore describing the air, we shall state it as consisting of "air molecules." Almost all substances which exist in the air are molecular, viz.: carbonic acid gas, water, ammonia, etc. Our term, therefore, is quite inclusive.

96. Anyone who carefully takes the trouble to make experiments and to think, is forced to regard the cold water molecule as a solid or nearly solid sphere (§ 97). It matters not how minute this sphere may be, for indeed it is very minute, it will obey the same laws of motion as any other larger solid sphere. We might illustrate the various physical properties of this water sphere (excepting chemical reaction and attraction) by a larger sphere, say a glass marble. We take such a marble, put it into a wash-hand basin having a hole at the bottom, and give it a whirl round the side of the basin, it goes whirling round and round, making smaller and smaller circles, and ultimately drops through the hole at the bottom; so, in like manner, does a quantity of smaller spheres—the water molecules. We fill the basin with water molecules, give them a whirl round with the hand, and the molecules roll round the basin and fall through the hole just as the glass marble did; the difference as regards the individual objects is only a difference of dimensions. We drop the marble into a cup, we let it drop some little distance or throw it with force, and the marble rebounds and jumps out of the cup; but let the marble fall gently into the cup and it is retained there. So likewise, if we force the water-molecules into a cup, as is done when we turn on the water from the tap too fast, they jump out of the cup and the cup is nearly empty; whereas if we let the water fall into the cup slowly and with little force, we can fill the cup.

97. "Molecules in motion move with velocities of all "degrees of intensity and in all directions. Molecules may "be regarded as spheres"* (§ 52).

98. Professor Cooke, in his "New Chemistry," † puts the case thus: "Consider what must be the form which a "mass of liquid molecules isolated in space would necessarily take. Remember that these molecules are moving "with perfect freedom within the body, but that the extent "of the motion of each molecule is limited by the attraction of the mass of the liquid. Remember also that, "according to the well-known principles of mechanics, "this attraction may be regarded as proceeding from a "single point, called the centre of gravity. Remember, "further, that the molecules have all the same moving "power, and you will see that the extreme limits of their "excursions to and fro through the liquid mass must be "on all sides at the same distance from the central point. ‡ "Hence the bounding surface will be that whose points are "all equally distant from the centre. I need not tell you "such a surface is a sphere, nor that a mass of liquid in "space always assumes a spherical form. The rain-drops "have taught every one this truth."

99. Now let us work upwards from this idea. Subject the water molecule — THE SPHERE — to decomposition, and it becomes split up into three objects, one

* Prof. Dewar's Lecture, Royal Institution, May 19th, 1892. Note—molecules in motion mean liquids, vapours, or gases.

† "The New Chemistry" of Josiah Parsons Cooke, LL.D. (10th edition), 1892, p. 50.

‡ This is purely a mathematical concept; we submit there is no centre of attraction in the molecule—the attractive force is on the outside.

an oxygen atom, the other two are hydrogen atoms, and we are met immediately face to face with our difficulties; because a liquid molecule, being a compound, may consist of two or more atoms—spheres.* What form, therefore, is it possible for the atom to have? If water molecules, being spheres, consisted of three objects of the same shape grouped together, then we could picture to the mind the ultimate particle to be of the shape of a third part of a sphere, thus (Fig. 19) :—

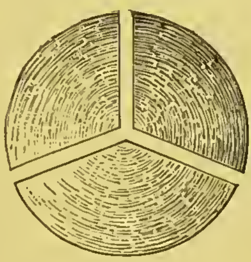

Fig. 19.

But to follow out the concept of the physicist, we must have the ultimate objects of which molecules are formed *while fixed and permanent in dimensions and shape* to be so constructed that two, three, four, five, six, or, in fact, any number can be fitted together, or, as it is so called, "bonded" together so that when thus grouped they become a sphere. The concept is impossible—absurd. Why, the most ordinary intelligent mind can

* The idea that gaseous atoms, or as the physicist calls them: molecules, are spheres is the only one the physicist can conceive, and he represents their physical condition as like "spherical balls." See "Theory of Heat," by J. Clerk Maxwell. 10th edition, 1891, p. 314 (§ 50).

see this issue; yet the trained mind, educated mathematically, cannot!

100. There is *prima facie* evidence, however, that the gaseous atom and molecule, as well as the liquid molecule, is a sphere; and we shall presently see how clearly this concept is brought out when we examine gaseous molecules in the Analyser (Fig. 12).

101. But suppose our evidence be the truth, that the ultimate particle—the atom—is a sphere when in a gaseous or liquid form. Now, Mr. Physicist, take three objects, each being a sphere, *each constant in dimensions and form*, and group them in such a manner that they become a sphere—a molecule! Why, the notion is untenable, impossible—nay, something more than absurd, it is puerile. Reader, take three marbles in your hand and so group them that that they shall *by grouping only* become one marble—can you do it? Yet this is the physicist's notion!

102. There is one concept, however, and, we believe, *one only*, which can be made to fit, and by this we get the idea that the liquid molecule is a sphere, and the atoms of which it consists are also spheres. Moreover, by it we can understand how two or more spheres in combination can exist as spheres and can occupy the same volume of space, either as combined or simple objects, at a given moment of time. This is a most important notion. We will now illustrate it.

103. We take a cubic inch of water, subject it to electrolysis or decomposition by means of the galvanic

current, there is an enormous absorption of ether which is given out when recomposition takes place, and we call one result of this latter reaction—Heat. When the cubic inch of water is decomposed, it increases under ordinary pressure and temperature to about 1,800 cubic inches.* Now, reader, picture this enormous increase of volume to the mind (§ 60) and endeavour to realise what has taken place in the conversion of the solid or nearly solid water molecule—the sphere, into the elastic gases, elastic spheres of hydrogen and oxygen.

Obviously, if a cubic inch of water expands to 1,800 cubic inches of gas, and the latter consists of objects, one of two results must take place—either the objects, being constant in dimensions, become further apart, or they increase *per se* in volume. The human mind cannot grasp any other alternative. The mathematical mind has decreed the former, it will *not look at* the latter view. If the latter view be true, then the mathematician assumes to himself a power to put his foot on Nature and stamp out its laws. Which will ultimately conquer, the physicist or Nature?

104. We submit the following concept is *the only one* the human mind can grasp, and we also submit that this

* "In the union of the two gases to liquid water, a condensation "of 1,800 times takes place, so that, in order to obtain a quart of "liquid water, we must burn 1,200 quarts of hydrogen gas, and take "from the air 600 quarts of pure oxygen." "The New Chemistry," by J. Parsons Cooke, LL.D. (10th edition), 1892, p. 218.

explains all the reactions. We believe the normal human mind is in harmony with Nature. The gaseous objects (oxygen and hydrogen) of which the water molecule is built up are elastic hollow spheres or spheroidal bodies filled with the fluid ether—that fluid we have just seen. When at a certain enlarged volume or temperature (being then super-saturated with ether), they have the power of entering into each other and thereby overwrapping each other in a concentric manner (Fig. 21), and by this process the vaporous water molecule is formed, being a sphere formed of spheres. Now, inasmuch as the latter when in the vaporous form—steam, under ordinary pressure has the volume in the mass of 2 to 3 of the heated gases, we have the evolution of one volume of free ether, the result of this bonding or chemical reaction (§ 81–*21*, also § 117). We thus obtain the steam molecule or molecule of water in the vaporous form—that is, super-saturated with ether. Let us now consider the reverse process—decomposition of water into the gases oxygen and hydrogen. The minute water molecule swells by the absorption of ether until it is highly super-saturated with ether; it is then a molecule of water in the condition we call steam. An excess of ether is now pressed on the water molecule, an increase of strain is the result; and immediately the gaseous objects unwrap themselves or—perhaps better expressed—they come out of each other as in Fig. 20. This concept is quite familiar to the mind educated by the microscope. If the factors are right, we venture to assert: *this is the*

only concept the human mind can grasp. Surely then it is true.

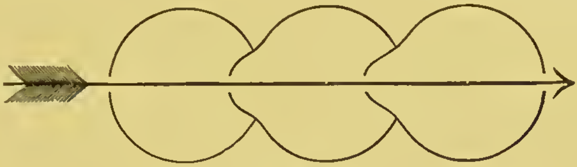

Fig. 20.

Diagram showing the decomposition of the water molecule (the arrow shows the direction of the current of ether).

Let us further consider the process of chemical combination, for it is important we should be understood. When three elastic gaseous objects, atoms of hydrogen and oxygen, combine to form a molecule of water, then they enter each other and become concentric, as shown in section, thus—

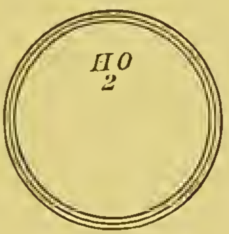

Fig. 21.

Diagram showing the first stage of chemical combination to form a water molecule, super-saturated with ether—steam.

We have now a large molecule of water highly charged or super-saturated with ether, two-thirds the volume of the three heated oxygen and hydrogen atoms, and we call this molecule steam. Immediately after the gaseous objects have thus combined, they contract and give out ether which is absorbed by the surrounding molecules—

the air, which are then said to be heated or increased in temperature. Thus the first reaction after chemical combination is a swollen molecule—steam, which contracts by rejection of ether to a molecule in the gaseous or fluid form. The usual result in air, being a molecule reduced to the temperature of the air molecules—that is, water in the gaseous condition.

This concept involves a power of atoms or molecules to open themselves at certain increased dimensions so that they can enter each other, and thus two or more spheres become one sphere. Moreover, this tends to the concept of polarity.

105. The elastic entities—gaseous atoms or molecules, except at the moment of combination, tend always to the spherical condition, because, as we shall presently see, normally internal pressure of ether—"strain," slightly exceeds the external pressure—"stress" (§ 81, *6*).

106. The term external pressure—that is, usually the pressure of the atmosphere—will be readily understood; but not the internal pressure, this we shall now proceed to more fully explain.

107. The whole of the reactions, except the reaction of combination and vibration, can be best understood by means of the following simple model. Its essential part consists of one of those common india-rubber balloons—mere toys—sold in the streets of London.

Take such a balloon, which is more or less angular or shrivelled in shape before inflation, insert a piece of glass tubing into the neck, and press air or water into the balloon. It expands, and just in proportion to the quantity of air or water the balloon holds, does the balloon increase in dimensions, always retaining the spheroidal shape. But nature has no glass tubes for the reaction,

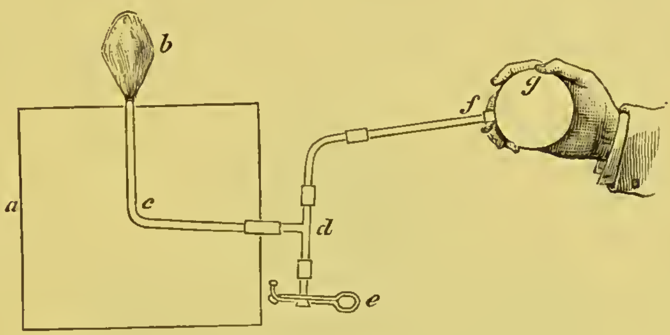

Fig. 22.

Diagram of the Section of Model:—*a* is a wooden box to support the india-rubber balloon *b*, which is shown unexpanded. The latter is connected with a piece of tubing *c*, which passes through the box *a*. This tubing is divided at *d*: one way is left open and can be closed by means of a clip *e*; the other way is connected by means of a small india-rubber force pump *f*, having a small hole *g*.*

it is a reaction arising from the inherent property of the gaseous object itself. The model (Fig. 23) makes the balloon appear to expand or contract by its own inherent power as the atom or molecule does in Nature. We will look at the model first as a diagram in section (Fig. 22)

* These convenient india-rubber force pumps can be obtained from Messrs. Townson & Mercer, 89, Bishopsgate Street Within, E.C.

viewing it at the side. Although water, which may be regarded as an incompressible fluid, more nearly represents the fact, for we regard ether as an incompressible fluid, yet for the purpose of working the model we use air as more convenient. The results are practically the same. Air then represents, in the working of the model, the fluid ether.

The model is worked by pressing the india-rubber ball by means of the hand, putting the thumb over the

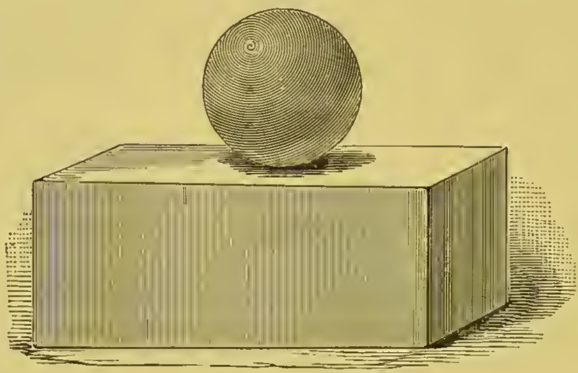

Fig. 23.

orifice *g*. The thumb acts as a valve. A second valve is in the apparatus to prevent the air returning. As the india-rubber ball is pressed, it forces the air into the elastic balloon *b*. The balloon thus increases in dimensions in proportion to the amount of air received and the consequent internal pressure, this is "strain" (§ 81, *6*). On the other hand, if we open the tube *c* by pressing the clip *e*, the balloon of its inherent power forces out the air, this is "stress" (§ 81, *6*), and it decreases in dimensions in proportion to the loss of air. Now turn the model

so as to view *only* the front (Fig. 23) and the illusion becomes very complete when we keep the manipulation quite out of view. Thus all that can be seen by the observer is: the balloon, now expanded, apparently resting on the wood box.

The balloon, which represents a *vastly enlarged* gaseous atom or molecule, has a certain dimension—a sphere of say 2 inches in diameter. This dimension may be called the "temperature" of the model gaseous atom or molecule.

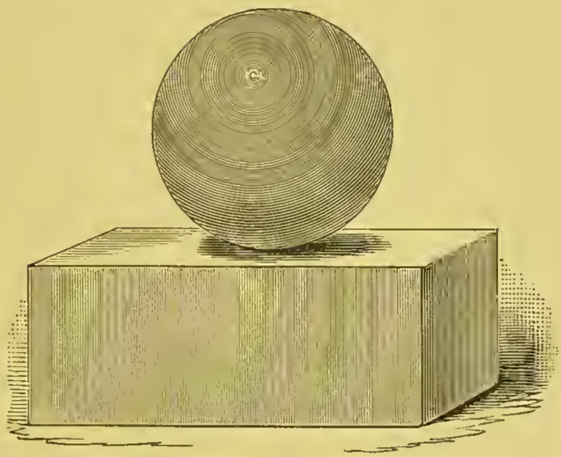

Fig. 24.

Set the apparatus in work by forcing more air into it, and it increases in dimensions to, say, a diameter of 3 inches (Fig. 24). This increase in dimension is an "increase of temperature," and the difference in dimension is what the physicist calls the co-efficient of expansion.

Next let the air out, and again our model is reduced to any dimensions we may elect, and just in the ratio to its loss of air, which represents ether, does it "fall in temperature." So that the dimension of the atom or

molecule is its temperature. By working the model in the way shown the balloon appears of its own inherent power to swell or contract—the illusion is very perfect, and, we venture to assert, exactly copies in a very much *exaggerated or magnified* manner the operations going on in Nature.

108. Only we must keep this in view: the dimension of the atom or molecule does not alter by the absorption or rejection of air as in the model, but of the incompressible fluid we have seen and called—ether. In fact, these elastic spheres—gaseous and vaporous atoms or molecules—in Nature, are very minute, but are, as far as dimensions go, quite within the range of the higher powers of the microscope and could be seen *if they were visible to our sense of sight,* but they are not—they are, as the late Dr. Tyndall has called them, "optically empty," and so is the fluid ether. Hence, under ordinary conditions, we cannot by our sense of sight, perceive any difference between ether and gases, but under the conditions of contrast in our experiments (§ § 90, 91) both are seen in mass.

109. Now see the advantages of this model over any mathematical reasoning. The process of increase of temperature or decrease of temperature is always a "continuous process." Such a process cannot be described by the mathematician, he can only approximate; his plant is not equal to the operation, and, not having the tools in his possession, he is fain to believe that Nature is to be levelled down to his powers, and what he cannot do—

Nature cannot, must not, *shall not do.* True the mathematician seeks to remedy the difficulty by narrowing the jumps to the smallest proportion possible ; but the jumps still exist, he cannot get rid of them (§ 19).

110. Having by means of the model obtained the fundamental idea, concept or notion, we proceed to enlarge.

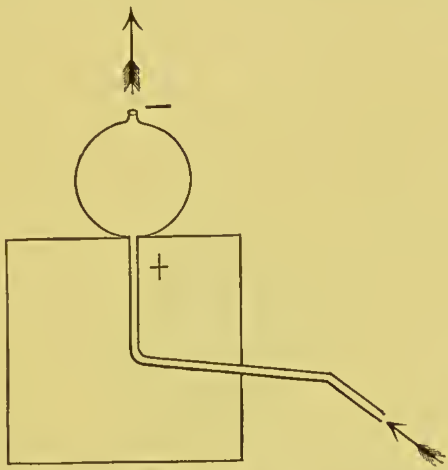

Fig. 25.

Diagram showing a section of a gaseous atom or molecule having an inflow + and an outflow −. The arrows show the direction of the current. The object is on a box as in Fig. 22.

The first thing which strikes the mind is, that in order to explain the process in Nature—that is, of ether travelling *through* the ultimate objects—we must have an inflow of ether *to*, and an outflow *from*, the atom or molecule.

Now alter our model-gaseous atom or molecule to one having an orifice at each end (Fig. 25) and we will call the inflow the plus end and mark it with the mathematical sign +, and the outflow the minus end and mark it with the sign −.

Such an elastic balloon is represented as a diagram—in section (Fig. 25). The inflow and outflow is made by means of two small pieces of glass tubing of the same length, cut off the same piece of tubing so that in both cases the bore is equal. The inflow + is connected with a foot blower, which is not shown. By putting the foot blower into motion we obtain a *continuous* flow of air

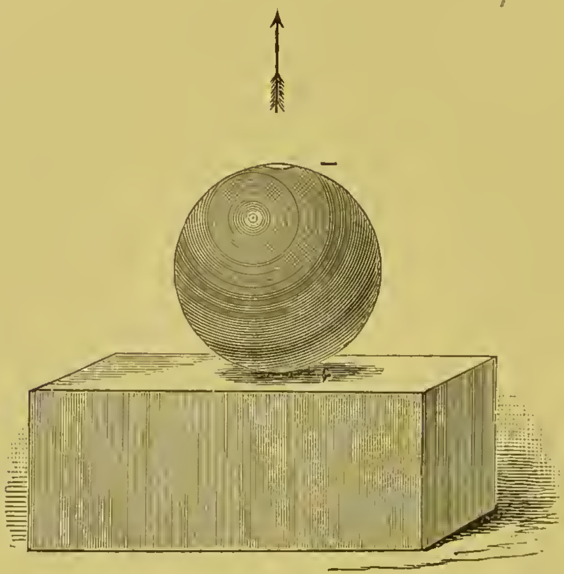

Fig. 26.

through the balloon and notice the result. The greater the flow through the balloon, or the greater the internal pressure (strain), *the larger is the dimension of the balloon*; the less the flow or the less the internal pressure, *the smaller is the balloon.* But there is another still more important fact to note, namely, when the internal pressure is constant and the external pressure is also constant, *the dimensions of the sphere is constant—i.e.*, temperature is

constant. We mount the balloon on a stand, as in the previous experiment (Fig. 26), but we will omit in the engraving the tubing at the outflow and more nearly represent what we believe is the true condition of things by an òutflow of variable dimensions, altering in proportion to the intensity of the current.

Thus we obtain the second concept. Substitute ether for air and we have: The dimensions of the gaseous atom or molecule or its temperature, is not only in proportion to the amount of ether held at a given moment, but in proportion to the internal pressure (strain) and the rapidity of the flow of the ether. Of course Nature has no glass tubing nor foot bellows, as we are compelled to use in our model. We have, it will be seen, our points of failure, as has the mathematician; we, however, fully recognise them.

Now remark what takes place in our apparatus by which we test our experiments. The thermometer shows the dimensions of molecules seen in the mass; while the galvanometer with the thermopile shows the current of the fluid ether.

III. But here is another factor. When there is no pressure in our model, over and above the pressure of the air, our balloon is not spherical at all. So that before we commence to bring our first model into operation, the balloon assumes the appearance of Fig. 27.

It is more or less angular. We bring into work the

model, and this form gradually decreases, and suddenly it assumes the spheroidal form.

112. So does the atom or molecule in Nature: with a certain very small quantity of ether absorbed, it often ceases to be spheroidal; it is angular or crystalline. An important concept. Not all matter follows this law, for not all solid matter at ordinary temperature is crystalline.

Fig. 27.

113. We are now in a position to consider the factors.

Taking the normal condition of the *gaseous* atom or molecule to be an elastic sphere filled with ether, then:

1. When the gaseous atom or molecule loses a certain quantity of ether, which immediately radiates through matter into space, it becomes reduced in dimensions to a very small object indeed, and becomes more solid, and this is the liquid condition. This object is so minute it cannot be seen even with the highest power of the microscope.

2. Inversely, when the very minute liquid atom or molecule receives an addition of ether, it becomes a larger sphere. It then is in a gaseous condition. The operation of the liquid molecule becoming a gaseous molecule is that of a sudden increase in size, producing a spring or jump, which can be seen by means of the microscope (§ 186).

3. When atoms or molecules have an excess of ether to surrounding media, or more than they can hold under their external conditions, so that they have to part with ether to surrounding media, then the molecules are *super-saturated* with ether. Instance, the case of steam (vapour) condensing to the condition of water gas.* On the other hand, when the molecules hold a relative deficit of ether, as when cold water molecules are mixed with hot water molecules, or cold air molecules mix with hot air molecules, the former in both cases are relatively *under-saturated* with ether. When the ether is in its natural proportion divided amongst both classes of molecules, so that each receives its proportion of ether according to its capacity, an equilibrium takes place—this is *saturation*. A thermometer explains all these reactions. It gives the ratio of super-saturation or under-saturation of the molecule to saturation. This is all; it gives no

* Water molecules in gaseous condition are best noticed in the singing water hammer (§ 206).

evidence of current of ether—we must go to the thermopile for that.

4. Let us repeat: to effect these reactions, therefore, there are two forces at work:—

1st. The internal pressure of the ether (strain),* forcing the sphere to expand.

2nd. And (on the surface of the earth) the external pressure arising from gravitation (§ 79) or other external pressure, and the inherent power of the molecule to contract, forcing the sphere to contract. When these forces are equal † (being opposite), then the dimensions are constant, *i.e.*, the temperature of the atom or molecule remains constant.

5. The fundamental properties of the gaseous entity is to contract and exude ether to form the liquid, and this liquid to further contract and further exude ether to form the solid. The latter in its contraction often forms the angular condition—the crystal.

But:—

6. The internal pressure of the fluid ether (strain) causes the atomic or molecular sphere to expand. This internal pressure or strain always exists at ordinary temperatures, and the reduction of this internal pressure causes the atomic or molecular sphere to contract.

---

* It must be borne in mind, ether is ever present; we live in an ocean of it, as do fishes live in a fluid—water (§ 195). It is this ever presence of ether which causes the normal condition of gas.

† It is questionable if these two forces are ever quite equal.

Hence:—

7. When the capacity of receiving ether is increased, by the increase of internal pressure (strain), we have an increase of volume, a rise in temperature. When the capacity is decreased, by the decrease of internal pressure (strain), we have a decrease of volume, a fall in temperature.

8. Inversely, when there is an increase of external pressure (stress), such exceeding the internal pressure, atoms and molecules give out ether (which radiates *through* surrounding media) and they become smaller in dimensions — this is a fall in temperature by pressure—stress.

In other words:—

9. When the inflow of ether exceeds the outflow, we have an increase in dimensions of the atom or molecule—a rise of temperature; when the outflow exceeds the inflow, we have a fall in temperature. The flow of ether through the atom and molecule is called by the physicist—radiation.

Now comes an important deduction.

10. *Before* a rise of temperature takes place there is an increase of ether absorbed, to a very small extent, by the atom or molecule, and when a fall of temperature takes place the atom or molecule contracts by exuding a very small quantity of ether as is shown in our model (§ 110).

The evidence tends to the view that electricity is such an action of ether on the atom and molecule as is explained in § 110, and this explains the "soaking in" and "soaking out" in electrical phenomena, as also does the intensity of the current of ether through the molecule explain the physicist's flow of ether resulting from the "electro-motive force" (§ 1 foot-note).*

114. We have to consider another important reaction. Not only does the relative internal pressure (strain) of the ether cause the atom or molecule to expand or contract, but the inherent power of the atom or molecule is to increase the conductivity *pro rata* to the pressure, so that each atom or molecule acts as a pump. The greater the amount of ether forced through the atom or molecule, the greater the activity of the atom or molecule exists to pump or force along this ether; or when external pressure (stress) is suddenly released (§ 155), we have a trembling or vibration of a very quick alternate expansion and contraction of the atom or molecule *per se*, and this when it exceeds a certain activity of vibration produces the phenomenon we call light, *i.e.*, incandescent atoms or molecules. †

* For this view see "Modern Views of Electricity," by Prof. Oliver J. Lodge. (Macmillan & Co.)

† How very nearly has the physicist approached the concept here given! "The molecule, though indestructible, is not a hard, "rigid body, but is capable of internal movements, and when they "are excited it emits rays; the wave length is a measure of the "time of vibration of the molecule"—"The Scientific Papers of

115. Thus: Firstly, when the free atom or molecule receives ether, the primary reaction is merely an act of expansion, or if vibration exists it is very minute. Secondly, when the internal pressure (strain) of ether on the free atom or molecule becomes greater it means not only a reaction of expansion, but a passing of ether from object to object—radiation. And, thirdly, when the internal pressure of ether is excessive, then we have the further reaction resulting from the strain causing the expansion of the atom or molecule (increase of temperature), the conduction of ether by these objects (radiation), and the vibration of the objects (light). This latter reaction takes place only when a certain value of strain exists, according to the specific class of atoms or molecules dealt with. When vibration sets in, we obtain as the result the molecular motion described by the physicist—impact and recoil. It is, however, a secondary result.

116. We have seen that ether is an anti-gravitating, incompressible fluid, optically empty, that it is deficient of colour, and when examined in the Analyser it appears (by contrast) absolutely black.* (§ 91).

James Clerk Maxwell," Cambridge University Press, 1890. Here, again, is the absurdity: What is meant by "internal movements" in a solid object—a sphere (§ 44 and § 97) of always constant volume. Mere words, but no idea.

* But suppose that ether is a compound fluid, being a mixture of certain ethers which when separated give colour without stating such as a fact, the author's mind tends to the concept.

What, then, is the result arising from this antigravitating function of ether? *Why, just in proportion to the absorption of ether does the free or fluid atom or molecule become larger and lighter, and rises from the earth's surface.* It is weighed in Nature's balance and is found wanting in its power to gravitate. It is as if an unseen hand had taken the object and raised it from the earth's surface without altering its attracting power.

This remarkable result we shall presently prove by experiment.

III.

117. Before, however, we prove the notions now placed before the reader, let us amplify and further consider the factors, for it is important, even at the risk of repetition, that the reader should fully grasp the ideas. We have stated (§ 103): When a cubic inch of water becomes decomposed into 1,800 cubic inches of gas, one of two events must take place.

Either: 1st. The atoms, *being constant in dimensions,* must become further apart in the ratio of 1 to 1,800.

Or: 2nd. The atoms or molecules must become, *per se,* larger in dimensions in the ratio of 1 to 1,800. If they increase in such a ratio, they may be objects within the reach of the higher powers of the microscope as far as their dimensions are concerned.

As the physicist cannot make the first idea harmonise with the known facts, we follow up the second.

We assume the gaseous atoms or molecules resulting from the decomposition of water to be spherical entities, elastic; not apart or impacting and repulsing each other, as is conceived by the physicist, but in contact and increased in dimensions *per se*. They have the same contact marbles would have when placed in a bottle.

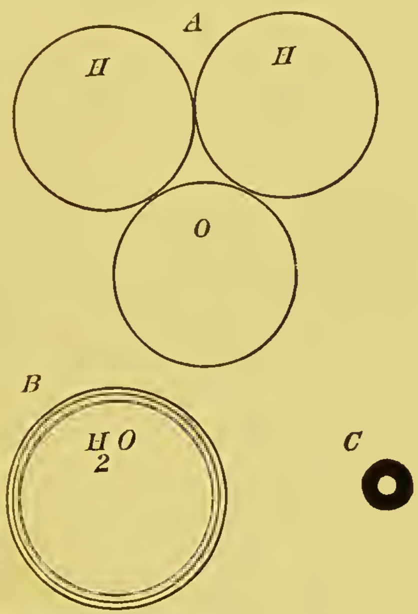

Fig. 28.

When, therefore, a molecule of water becomes decomposed, it is split up into objects which occupy the volume of 1,800 times the volume of the molecule of water, as shown in the diagram (Fig. 28); but as it is difficult to represent a ratio of 1,800 to 1, we shall only attempt to illustrate the concept without regard to relative dimensions.

Explanation of Diagram (Fig. 28).—The circles represent sections of spheres—atoms or molecules. *A* represents three

objects—two hydrogen, one oxygen—at ordinary temperature, say 60° Fahr. Before combination they absorb ether and increase in dimensions or temperature. When combination takes place they overwrap each other and become concentric; at the instant of combination free ether is evolved, the result of the combination is a molecule of vapour (steam) *B*, which in volume is two-thirds the united volumes of *A*, all now being at the same temperature, about 212° Fahr.,* thus one volume of ether is let free. The molecule of water (vapour), when mixing with air at, say 60° Fahr., gives out its ether, which radiates *through* matter into space and becomes a water molecule in the gaseous form of the dimensions of either *H* or *O* (*A*). Thus Avogadro's law is maintained. If from this molecule of water, in the gaseous condition, ether is abstracted by pressure or otherwise, it suddenly contracts to a very minute sphere, which is the water molecule in the liquid condition *C* (§ 186); at the same time the ether radiates. The volume of the latter should be in the ratio of 1 to 1,800 to the three gaseous objects, and the evolution of ether in the like proportions, which is quickly absorbed and conducted away by the air.

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* Dr. Hofmann's experiment explains this. *See* "Watts' Manual of Chemistry" (2nd edition), 1889, p. 65. In considering this experiment, it must be noticed the gases oxygen and hydrogen are raised in temperature to about the temperature of boiling water, and then they do not combine until a current of ether—shown by the electric spark—is passed through the eudiometer tube.

Perhaps the idea of increase and decrease of dimensions of atoms or molecules *of a solid* can be best illustrated in the following manner :—

Build up a rectangular mass, having greater length than breadth and a greater breadth than depth, of minute spheres, cohering to each other ; such may be done by carefully gumming together small spherical bodies—seeds will do. Now, by photography, make a lantern slide of such an object, and by means of the lantern throw the object on the screen.

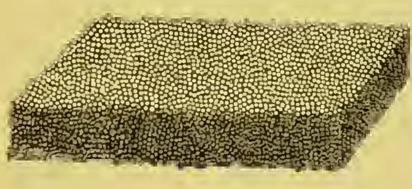

Fig. 29.

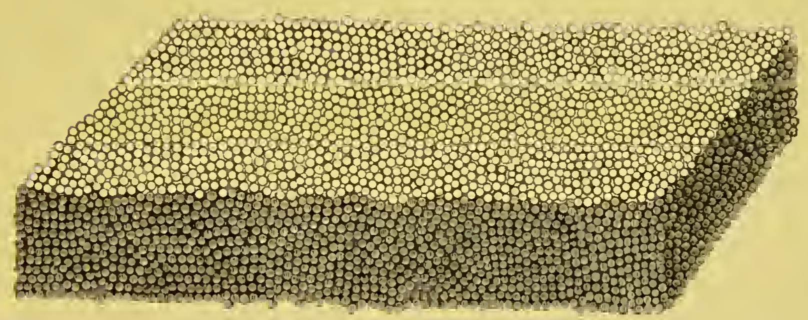

Fig. 30.

We have then a representation upon the screen of a solid object built up of molecules (Fig. 29). This represents a solid of a certain temperature.

This object, then, is what the geometrician calls a *parallelopiped*, built up of spheres or spheroidal

bodies.* We have purposely avoided a perfect geometrical figure, and allowed certain irregularities to exist.

We now hypothetically increase the temperature of such a solid, and we show the reaction upon the screen. This is done by removing the screen further away from the lantern, and we note the result: the *parallelopiped* becomes larger not by the spheres becoming further apart, but by each sphere or spheroidal body becoming larger *per se* (Fig. 30).

We have here an increase of dimensions, *without an alteration of contour—there is no relative displacement*—there is molecular motion, but not in the sense the physicists use the word: every molecule has been displaced, but not relatively displaced. In a word, we venture to assert the illustration on the screen *exactly* reproduces the fact, which takes place in Nature. Compare this idea with the physicist's concept expressed in § 23 and § 24, and then consider how unutterably absurd is his idea founded solely on mathematical notions.

Note how perfectly this illustration explains the actual reactions known to have taken place in the Egyptian coin, illustrated in § 58, Fig. 4. In the illustration given every irregularity of the solid is magnified by increase of temperature, and this is what takes place in the Egyptian coin. Hence the configuration and contour remain constant. We venture to assert that no other notion can explain these reactions.

* It is not necessary that in solids the molecules must be always of these forms (§ 180); any conceivable form will respond to the conception (§ 143, 7).

IV.

118. The reader having, we trust, fully grasped the situation, we have recourse again to our box—the Analyser, which is now free from motes. We draw the box in section, thus (Fig. 31):

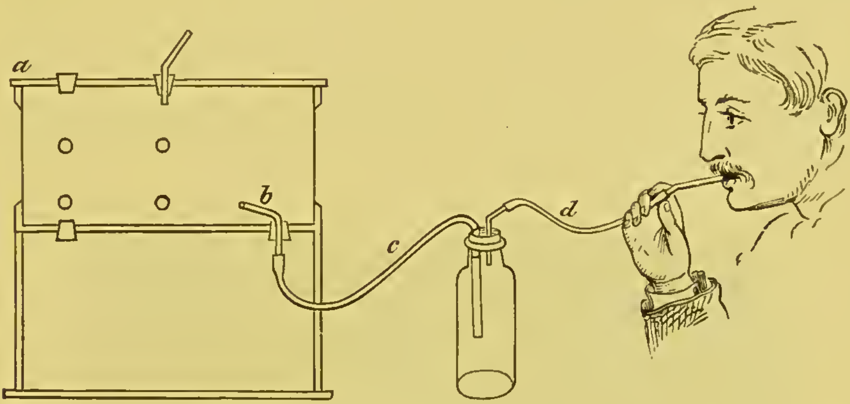

Fig. 31.

a is the section of the Analyser (Fig. 12) free from motes, but filled with "optically empty" elastic spheres—the air molecules; *b* is a bent glass tube about ½-inch in diameter; *c* is a piece of india-rubber tubing connecting the glass tube in the box with a bottle and passing through a cork; *d* is a small india-rubber tube fitted with a glass mouthpiece.

We loosen the cork of the bottle, pinch the tube *c* with the finger and thumb and blow into the bottle smoke—any smoke will do, but tobacco smoke is the easiest to fill it with—until the fog in the bottle is as dense as possible. We may call the contents of the bottle air saturated with motes.

We release the pinching of the tube *c* and press the cork in tight. The bottle is now filled with motes, but

none have yet entered the Analyser. The Analyser is, of course, strongly illuminated by means of the lantern (Fig. 12).

119. Now, by means of the mouth, we blow through the small tube a very small puff of air and note the reaction in the invisible gaseous objects—the air molecules—with which the box is filled.

There comes out of the tube what looks like a small *medusa* or jelly-fish; it is a beautiful object, and as instructive as it is beautiful (Fig. 32).

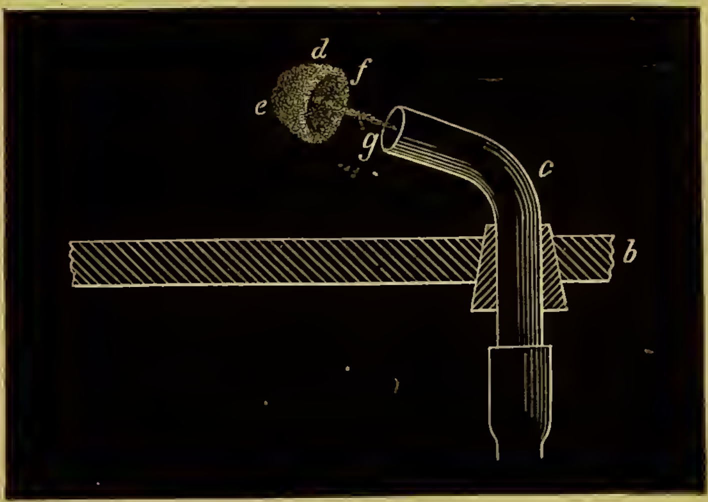

Fig. 32.

b, bottom of Analyser; *c*, glass tube; *d*, incipient vortex ring—the jelly-fish-like object; *e*, crown of the jelly-fish-like object; *f*, its periphery; *g*, its tail.

By the force of the puff of air from the lungs this object goes on floating through the air in the Analyser from right to left approaching the light, and as it goes along it alters in structure. All the

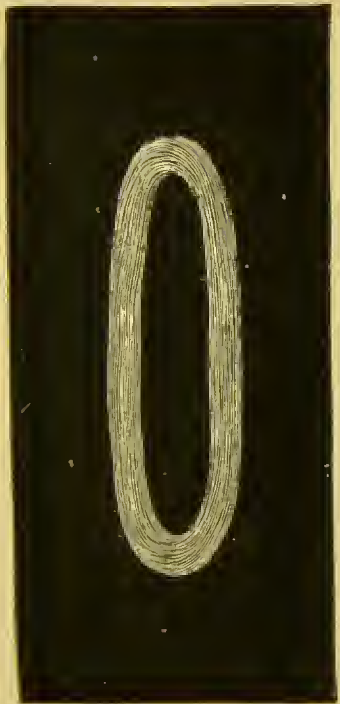

Fig. 34.

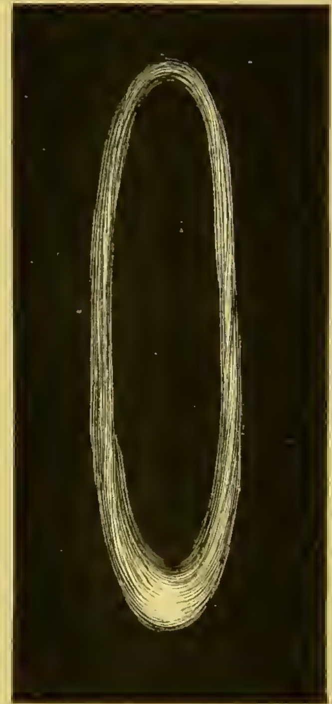

Fig. 35.

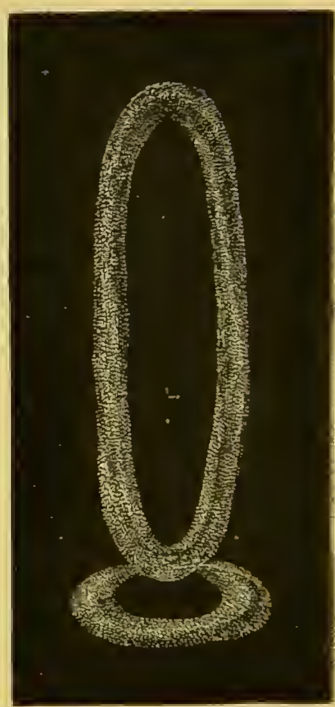

Fig. 36

time and during its changes, the motes are powerfully illuminated.

120. Let us study the changes going on: At first the border or periphery of the umbrella-shaped object *f* curls under itself; the crown *e*, if we may so call it, dies away by travelling towards the periphery, and the stream of motes forming the tail *g* becomes absorbed in the air, so that if we made a section of this object it would appear thus (Fig. 33). The curling of the ring is distinctly visible.

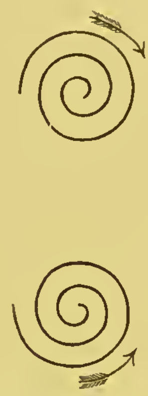

Fig. 33.

Diagram showing section of a vortex ring in its first stage. The arrows show the direction of the motion of the molecules.

This is the section of a vortex ring into which the jelly-fish-like object has differentiated. As it moves along it expands and elongates, but as it goes on floating towards the light an important alteration takes place.

The ring no longer looks approximately homogeneous, but like white threads—indeed, it looks like a skein of white silk floating in the air (Fig. 34); at the same time as it enlarges and elongates it becomes denser at the bottom (Fig. 35). It now loses the thread-like appearance.

Presently, as it continues floating along towards the light, this thick part differentiates into another vortex ring,

which latter is horizontal, as in Fig. 36, and it gradually separates from the parent ring and falls to the bottom of the Analyser.

Next the objects get gradually dissipated into the air and the beautiful things are lost. Thus we have seen the birth, growth, differentiation, reproduction, and death of a vortex ring.

121. How are we to explain these reactions? It is very simple. The motes which are illuminated exist

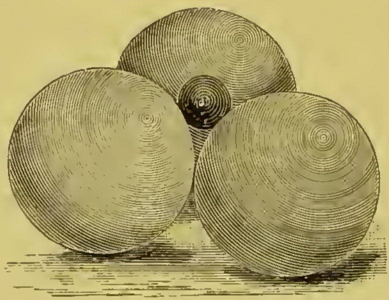

Fig. 37.

suspended or buoyed up between the elastic transparent or "optically empty" spheres, as illustrated in Fig. 37, where the three large spheres represent the *invisible* air molecules, and the small object suspended or buoyed up between is the *visible* mote. We must remember that the weight or pressure of the atmosphere (§ 79) causes the air molecules to tend to be in contact or to press against each other.

The invisible air molecules are saturated with these motes as they come out of the tube, that is, there is

more than one mote between each group of air molecules. We must steadily keep in mind, the motes only are visible, not the air molecules. But the puff of air sent out a number of these mote-charged spheres into the Analyser, which assumed the forms we have already described. Let us see if we can graphically describe what has taken place. Reader, take into your hand an india-rubber ball, or a glass marble, or any sphere. Now, roll the sphere on the table as you would a billiard ball, and notice the motion is of a twofold character, namely, a motion of translation in space from one place on the table to another place, and a rolling motion—a rotation of the sphere. If, instead of rolling the ball on the table, you throw it through the air, above the table and not touching it, but without giving it any initial twist, you will find the ball has only one motion—a motion of translation, and not of rotation. The rotation in the first place arises from the resistance on one side of the ball produced by its contact or attraction to the table. On the other hand, when the ball is thrown in the air, the resistance of the air is equal at the sides; hence there is no rotation.

122. Well, then, we have the spheres (air molecules) going out of this tube through the push or the puff of air pushing themselves into a mass of elastic spheres (air molecules), which the Analyser holds. The spheres in contact with the glass tube get the motion of translation and rotation, and a lag resulting from the resistance of the

tube, while the spheres in the centre of the tube get no resistance at the sides from the contact with the solid, hence there is no rotation in the latter. These form the tail *g* of the object (Fig. 32). The reactions of resistance or friction and rotation and the lag form the dome-shaped head of the jelly-fish-like object, and produce an order of motion of the gaseous spheres which makes the form of the vortex ring (Fig. 33). Thus the reaction is the continuance of the rotation of the spheres causing the crown *c* (Fig. 32) to be sucked in and to die out, and the edge or periphery of the object *f* to curl within itself (Fig. 33). The illuminated motes distinctly show the reaction. The object is now a vortex ring; but the air molecules, being the spheres which form the ring, are heavily charged with the motes, and the latter begin to gravitate or fall between and to draw down the invisible air molecules, and thus elongate the vortex ring. The fall of the motes is so rapid that the eye cannot distinguish their individuality, hence they look like white threads. The motes are now massed at the bottom of the vortex ring, and they begin by their sudden fall to make an inverse rotation of the invisible spheres—molecules of air; the motes get distributed amongst them, and thus the second vortex ring is formed. Immediately the force resulting from the puff of air is spent, the motes get dispersed amongst the invisible air molecules, and after a short time they are fairly distributed, and contribute to build up the fog inside the Analyser. We have taken great care to explain these very beautiful reactions. We trust we

have been clear, and conveyed them in a form which is quite intelligible. The reactions are very complex. In spite of the clearest description and the best of illustrations, we feel that no description can equal the personal observations of these beautiful and important objects. We have been careful to fully explain the whole process, in the hope that the reader will repeat the experiment.

123. Now let us consider—1. The form of the vortex ring is created by the motion of the air molecules—spheres of which the ring is composed—these spheres lying in contact, as marbles would lie in a vessel. 2. The elongation and reproduction of the ring is formed by the gravitating of the motes, they exist in such numbers that the air molecules cannot buoy them all up. 3. When the motes get fairly distributed amongst the air vesicles gravitation ceases * and they are held singly buoyed up between the air molecules or vesicles of ether, as illustrated in Fig. 37.

124. How do we know all this? The answer is given by two important experiments.

We will repeat the foregoing experiment in an inverse manner. Instead of making vortex rings charged with motes, we will make "optically empty" or black vortex rings in the air in the Analyser charged with motes.

* The motes (most probably) become eventually attracted by all sides of the Analyser, and thus they disappear.

We clear the bottle of motes by blowing all the contained air into the Analyser until the stream of air comes into the Analyser quite black instead of white; this is a sign the air entering the box is devoid of motes (§89, §90). Perhaps there may not be sufficient motes in the Analyser, then some more must be added through the tube *h* (Fig. 12). The bottle is now free of motes, and the Analyser is filled with fog. We give the puff of air into the bottle and there comes out the same jelly-fish-like object, which differentiates into the vortex ring as before. It is now quite black; *it does not elongate; there are no thread-like objects; there is no second vortex ring.* The reply given is absolutely perfect—conclusive. The motes are the cause of the elongation and the production of the second ring.

125. We have said "when the motes get fairly distributed amongst the air vesicles, gravitation ceases, and they are held singly buoyed up between the air molecules or vesicles of ether" (§ 123). To prove this is, to our mind, a most important and conclusive physical experiment. We have already seen the motes are suspended in the air and they are fairly evenly distributed—*i.e.*, are about equally distant, mote from mote (§ 87).

We take a small glass trough about $\frac{1}{8}$-inch depth, such as is used by the microscopist. We fit a piece of cork (Fig. 38, *a*) into the mouth of the trough. We make a piece of glass tubing large enough to hold a cigarette, tapered to a fine tube and bent at right angles *b*, which

passes through the cork. We pass a fine glass tube *c* bent at right angles through the cork, and connect with a piece of india-rubber tubing, which has a glass mouthpiece. When the cigarette is lighted, suck the air by means of the mouthpiece and the smoke will drop into the trough as illustrated (Fig. 38).

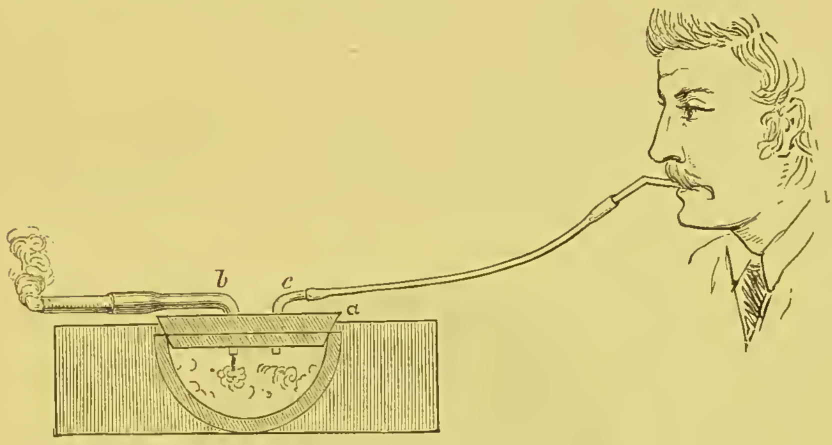

Fig. 38.

We look at these motes by means of the microscope, using ½-inch objective, a parabolic condenser, or in default a spot lens, illuminating by means of a very strong light—sunlight, electric, or oxy-hydrogen light--either does equally well.

We see the individual motes each separate, *never in contact, but at a fairly even distance apart, all in a state of intense vibration*, such as we would expect to see if the colourless vesicles of ether were intensely vibrating—not, however, a vibration of impact and recoil, but a quick vibration of alternate expansion and contraction of the invisible gaseous molecule *per se*, carrying with this vibration the illuminated mote and causing the mote to

move in sympathy with the vibration of the gaseous molecule. The motes are also moving about in all directions.

Moreover, the mote does not look quite like an illuminated speck, but it looks like a small white sphere *with a pair of wings!* Our artist has endeavoured to show these motes in Fig. 39, but again it is impossible to do justice by illustration. The reader must observe himself, and he should absolutely abstain from criticism until he has seen the objects themselves. It must be kept in mind that the objects seen under the microscope are inverted.

Fig. 39.

What are those wing-like objects? The author's mind tends to the idea that they are the illumination of part of the gaseous molecule itself, and thus we obtain the first glimpse of the ultimate particle when in a gaseous condition—the vesicle of ether. One fact seems to confirm this view—namely, the position of the wing-like objects depends upon the angle of illumination. Sometimes both

wings are on one side of the mote, sometimes they are inverted. We have drawn the reader's attention (§ 87) to the fact that when the Analyser is charged not too densely with these motes and a very strong illuminated power used, the individual mote can be seen even with the naked eye, if the eyesight is good, and the equal distance of each mote from its neighbour is clearly seen.

126. Let us try, if we can by analogy, convey the concept. Suppose we had a quantity of these light, elastic transparent (or invisible), but relatively large spheres—the air molcules—lying in contact, as in Fig. 37; and suppose each of these spheres were vibrating—a quick, but limited, vibration of expansion and contraction, *per se*—and we were to put in the corner, where the spheres touch each other, a relatively heavy object, the mote: the elastic spheres would, by their pressing together, buoy up the mote, although it is heavier than the invisible elastic spheres—the air molecules. What would take place as the elastic spheres vibrated? Why, they would move the mote to and fro. The denser mote would, by impact and recoil, strike in succession each elastic sphere. Just as the drummer's drum-stick strikes the drum and causes the parchment to vibrate, so do these motes strike these elastic vesicles of which the air is composed. Within the area of the surface of the sphere on which the mote impinges there would be an excessive vibration, and this is the part which becomes visible and forms the wings. The mind can fully grasp the concept, and the reaction is very much like what

we see by means of the microscope. The following diagram (Fig. 40) illustrates in section the reaction, where *a* is the mote, *b b* the gaseous objects, the dotted line shows the invisible part of the vesicle, the continuous line

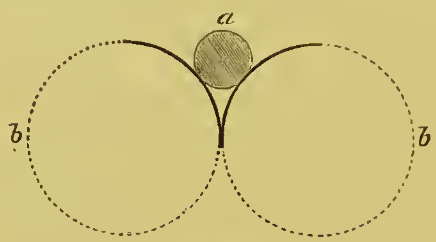

Fig 40.

shows the illuminated part. Notice that in Fig. 39 the wing-like objects are inverted. We invert Fig. 40 and show the illuminated parts, Fig. 41. In Fig. 41a, we draw the illuminated portion of Fig. 40 as it would appear in the experiment. Compare with Fig. 39, making allowance for dimensions of the diagram, and notice how completely the concept is conveyed.

Fig. 41.

Fig. 41a.

There is one very important fact supporting the above view, namely: when the motes are viewed by means of sunlight, a certain number of them are without the wings, but instead they are surrounded with luminous

concentric rings—Newton's rings, but they are simply black rings. It would appear as if the molecules were seen with the mote exactly between the eye and the light reflected from the mirror, and thus we see the operation of the striking of the molecule by the mote in plane. The vibration waves are thus seen. The following diagram fairly represents the object, but in an exaggerated manner.

Fig. 41b.

127. Now let us consider: If the hypothesis of the physicist were true, namely, that the molecules (objects far beyond the highest powers of our microscopes) were at an enormous average distance apart vibrating by impact and recoil, or some such analogous motion, then these motes should move with such a motion; and considering the vastly minute dimensions of the gaseous molecule as held by this hypothesis, then the motes should appear to impact and recoil with the impact and recoil of the gaseous molecule. Moreover, with molecules with such huge average gaps between them, there should be no sustaining power, no buoying up, which most certainly takes place, but the motes should instantly drop between the gaseous atoms by their obviously superior gravitating power. In a word, the motes in the sunbeam could not exist.

V.

128. In § § 91 to 93 we demonstrated the fact that we could see the fluid ether, and we showed its anti-gravitating property; we also stated (§ 94) that there was more taking place than the displacing of the air molecules by the ether. We now proceed to prove this.

We clear the Analyser of motes, leaving the apparatus in the condition of Fig. 31. The bottle is charged with motes, and we take out the cork *c* or *e* (Fig. 12) and insert in the hole the heated glass rod, or rod charged with and exuding ether (§ 91). There is no reaction visible as yet, because there are no motes to effect the contrast necessary to make the ether visible. We make white vortex rings as previously described; they are perfectly within our control, as by altering the position of the tube *c* (Fig. 32) we can be made to move in any direction. We cause them to gently float up to the rod, and note the marvellous reactions which take place directly the vortex ring touches the fluid ether, which is, under these conditions, invisible. The ring seems to strike an invisible wall, it indeed strikes the stream of ether we have seen. The ring elongates by the side of the rising ether, partakes of its motion, and then is almost instantaneously destroyed. The vesicles of ether—*i.e.*, molecules of air which buoy up the motes, and which thus make the ring visible, receive by contact more ether and expand, and thus partake of the antigravitating reaction of ether; hence vesicle follows

vesicle and they rise in the air, and thus the ring is destroyed. The reaction is very beautiful and should be seen before any comment is made. But let the vortex ring pass, even immediately, beneath the rod and no reaction takes place, thus proving that there is no great disturbance of the air molecules beneath the rod, and that the ether comes out of the rod.

129. There is another way of seeing this reaction, by sparingly filling the Analyser with motes and clearing the bottle of motes. Now the ether is visible as explained in § 91. We proceed to repeat the experiment by causing the black vortex rings (§ 124) to float up to the rod. The reaction is just the same as in the rings charged with motes, but here the advantage is, in seeing both the free ether ascending from the rod charged with ether at the same time we see the black ring and its destruction. This ascending of these gaseous molecules—vesicles of ether, by the absorption of more of the fluid ether is called by the physicist a "convection current"—a term hitherto expressed, but not explained.

130. There is yet another way to view these reactions: sparingly charge the box with motes, so that each mote can be distinctly seen, and insert the rod charged with ether. By concentrating the light by means of a lens, we can see the reaction caused by the vesicles of ether—the air molecules, with their motes buoyed up between them, chasing each other each from the sides of the stream of free ether.

Of course the gases are invisible, the illuminated motes show the movements of the gaseous molecules.

131. In all cases directly the rod gets to the temperature of the air the reactions cease.

132. We now proceed to an important experiment. We believe Lord Rayleigh first drew attention to it in a communication to the Royal Society, December 8th, 1882, but he could not explain the experiment. Instead of viewing the glass rod when it is charged with an excess of ether, being super-saturated with it, and giving the reaction of exudation of ether, take out the ether which exists in the rod at the temperature of the atmosphere. This is easily done by inserting the rod in a freezing mixture. The rod thereon loses the ether and contracts in dimensions, and the mixture receives the ether. We carefully dry the cold rod and then examine it, the same way as we previously examined the rod super-saturated with ether —that is, in the Analyser charged with motes, putting the rod through the hole *b*. The result is perfectly harmonious with the previous experiments, and it is this: Immediately the rod is inserted the gaseous molecules of which the air is composed give up their *latent* ether to the rod, which absorbs it, and it increases in dimensions. Now as each molecule looses its ether it contracts, becomes denser, and falls beneath the rod, a current of falling molecules immediately beginning to chase each other downwards. As they fall the smaller contracted vesicles become visible, they

appear as a white vapour falling vertically from and beneath the rod; these contracted molecules or groups of molecules are whiter and heavier than the white motes. Figure 42 gives an idea (in section) of the reaction. To see this reaction, it is necessary to illuminate the Analyser by means of the electric light.

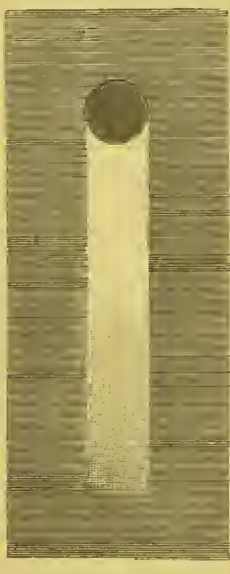

Fig. 42.

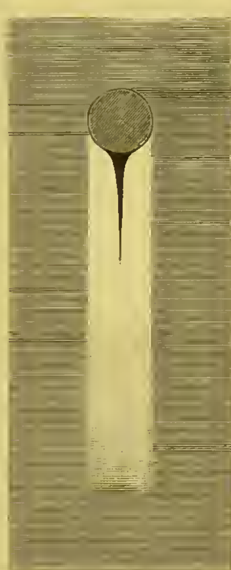

Fig. 43.

There are two reactions here seen. First: a steady and increasing fall of molecules, and a decrease in their dimensions. What is the consequence? After a few seconds such an acceleration is given and these reactions take place so quickly that there is a minute vacuum beneath the rod, and of course this vacuum, being devoid of luminous motes, is "optically empty," it appears quite black. Fig. 43 shows the reaction in section. It seems very absurd to say we can see a vacuum; but if the

factors are correct, there can be no doubt we see this vacuum.

If we test this reaction with the vortex rings, we get exactly the inverse reactions as from the heated rod; the rings are perfect above the rod and are destroyed beneath the rod directly they come in contact with the white, contracted molecules.

133. We must not forget to notice there is a black coat of ether surrounding the heated rod or rod supersaturated with ether, and as it cools it disappears; on the other hand, there is an entire absence of this black coat in the cold rod or rod devoid of this ether; also that dust-motes are deposited on the cold rod, showing that there is absolute contact between the rod and the air-molecules—the vesicles of ether. In the heated rod the free ether exuding out of it prevents the contact of the air-molecules and the rod—an important difference. Also we must note how very small the vacuum space is beneath the cold rod as compared to the appearance of the very much larger amount of free ether ascending from the heated rod.

134. If it were required to conclusively prove that the gaseous atom or molecule is a vesicle of ether, besides these experiments, which for the first time immediately appeal to our sense of sight, the following, we believe, does this.

Consider the apparatus called the fire-syringe: it consists of a cylinder closed at the bottom, into which is inserted a piston, which is packed with a leather ring to keep the contents of the cylinder air-tight. We have drawn it in section, Fig. 44.

Here when we press the piston down we press together the vesicles of ether—the air-molecules, and as we force them into a smaller space they give out their ether; but when we pull up the piston we allow the vesicles to expand *of their own inherent power*, and as they expand they absorb ether. Note how elastic the gases are, press in the piston and then release the pressure, and the piston goes out of itself. There is a small space *a* in the piston into which we can insert a piece of German tinder, which has great affinity for this ether. We sharply press the piston, the vesicles of ether—the air molecules, contract, give out their ether, the tinder and the cylinder absorb it, and the former immediately becomes incandescent.*

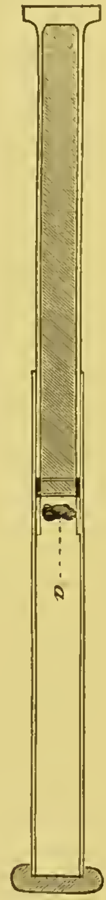

Fig. 44.

135. It may be asked, how is it, in our experiments, the fluid ether is seen in such small quantities? The reply

* In making this experiment the author previously dips the tinder in a solution of saltpetre. When dry the experiment is more certain. On one occasion he dried the tinder before the fire, and when it was dry and hot he made the experiment. *The tinder exploded!* Temperature was the only factor which produced the explosion.

is: the molecules of gases of which air is composed, by their being free in motion, absorb or "lick up" the ether, and run away, as it were, with it so quickly, that little of the ether is left free to be seen.

There is, however, a way of seeing this fluid in much larger quantities, and the experiments are very instructive.

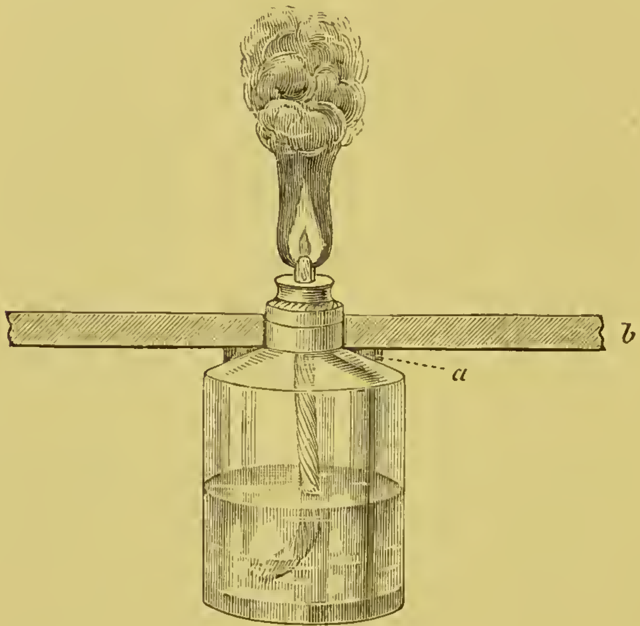

Fig. 45.

Black material surrounding and rising from a spirit lamp: *b* section of bottom of Analyser.

We take the Analyser in the condition of Fig. 12. We charge it with motes, and there is the brilliantly illuminated cone of light from the lantern. We take out the corks *a' a*, and we insert in the lower hole a lighted spirit lamp; the smaller the flame the better the reaction is seen. Fig. 45 shows what is seen.

Between the shoulder of the spirit lamp and the bottom of the Analyser is put a common india-rubber band *a*—this stops any inflow of air. Now there arises from the flame of the spirit lamp a mass of "black-something," looking like black steam—it is not, however, wholly steam. The reaction is most perfectly marked, especially at the lower part of the flame. Again we repeat, no illustration can show the beauty of the real object.

136. What is this "black something?" It consists of molecules of gases super-saturated with ether and free

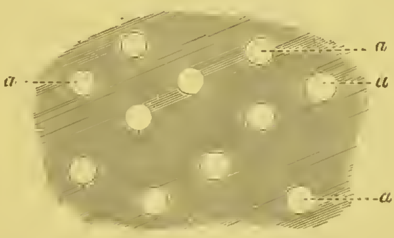

Fig. 46.

ether, or ether in the same condition as comes off from the heated rod, the result of chemical reaction. The free ether, instead of existing in a stream and ascending from the rod, as in Figs. 17, 18, now exists between the gaseous molecules super-saturated with ether. The diagram (Fig. 46) shows the condition of things. The black shading between the gaseous molecules represents the free ether; the spheres *a a* represent the super-saturated and expanded vesicles of ether—the gaseous molecules. In this condition the gaseous molecules and ether are both

"optically empty" or invisible, hence the mass rising from the spirit lamp appears black.

137. How is it this condition exists? We refer the reader to § 104 and § 117. We must fully grasp the concept. We have shown that the only possible notion the mind can grasp, in order to understand the physical reactions called "chemical combination" to form a free object—a sphere, is to know that when the vesicles of ether (gaseous atoms and molecules) are expanded to certain dimensions by being super-saturated with ether, they overwrap each other in a concentric manner and thus form a new sphere—a molecule, which in its initial condition is an expanded molecule—that is, super-saturated with ether. At the moment of overwrapping or combination "chemical reaction" is said to take place. This concept leads to important results and we must fully understand it.

138. Now we will endeavour to illustrate the whole of the reactions which take place in our experiment shown in Fig. 45.

The liquid—spirits of wine, in the lamp consists of minute nearly solid spheres called "molecules." Let us illustrate these spheres by the little sphere *C*, Fig. 28. We will endeavour to convey a very rough ratio of dimensions, but it is impossible to convey a true ratio, for, in the first place, the molecule of liquids is to our minds infinitely small, the aided eye cannot see it nor

the mind grasp the minuteness of its dimensions. It is only when it is enormously swollen by the absorption of ether that its dimensions come within the reach of the human eye.

Well then, the reservoir of the lamp is filled with these very minute objects—molecules, compound bodies holding at ordinary temperature a very small quantity of the fluid ether. Why do we say this? Because they are capable of decreasing in dimensions or can decrease in temperature. This reaction we see in the spirit thermometer. When each molecule comes in contact with the wick, from its inherent attractive power and the attractive power of the molecules of which the wick is composed, it creeps up the wick and rises to the top or exposed part of the wick. This process is called by the physicist "capillary attraction." Thus molecules after molecules get to the exposed surface of the wick. At this exposed part, before the lamp is lit, the spirit molecules are in contact with the air molecules, and they are in a favourable condition to seize part of the ether contained in each air molecule. We shall *see* this reaction further on (§ 186 and § 190). The air objects are thereby robbed of a proportion of their ether, which radiates *to* the spirit molecules; the latter seize this ether and expand, and thus the liquid molecules (the spirit) become in the gaseous condition. The gaseous molecules of spirit now mix with the gaseous molecules of which the air consists, and they become "optically empty," or

invisible. Thus the liquid spirit gradually disappears. This reaction is called by the physicists "evaporation," and by this notion Avogadro's law is sustained, for when the spirit molecules become gaseous they are about the dimensions of the air molecules.

139. But we take a mass of incandescent vibrating * molecules such as we have in a lighted lucifer match. We bring these incandescent molecules—*i.e.*, molecules giving out the fluid ether at an enormous rate, to the spirit lamp, and then all is changed. Instead of the molecules of spirit slowly evaporating amongst the air molecules, an outer zone of molecules surrounding the wick becomes incandescent: a chamber is now formed mainly filled with molecules absorbing ether inside the now incandescent molecules in the candle; it is a familiar object, blue-black in appearance. Into this chamber the molecules rise by the so-called capillary attraction; here they absorb the free ether resulting from the chemical reaction of the now luminous molecules, they swell in dimensions by the absorption of ether, they are super-saturated, they are now in the gaseous condition as represented by the diagram, Fig. 28 *B*. As new molecules rise, they become in their turn incandescent, and evolve free ether for the constantly rising fresh molecules, and so the process goes on as long as the spirit lasts. In the diagram (Fig. 28) the number of concentric rings, or number of atoms of which the spirit molecule is

* For the definition of this vibration (*see* § 81, *15*, *23*).

composed, fails, as the spirit molecule consists of more than three atoms, but the principle is shown in the diagram.

Each ring in the diagram should represent a section of an expanded gaseous atom, and the central portion, the volume of ether absorbed. Now it is at the moment when this expansion is at its maximum the reaction takes place,* as explained in § 104. The molecules then become violently vibrating; they are incandescent gaseous molecules. These form the so-called flame of the spirit lamp. Thus the oxygen molecules at a high temperature, being in the presence of molecules containing ether under great internal pressure—strain (§ 81, *6*, § 113), (that is, spirit of wine molecules at a high temperature), are placed in a condition to combine with the products arising from the decomposition of the spirit molecule, and we have the complex reactions, called "chemical reactions." Whenever these reactions take place so fast that the free ether resulting from the chemical actions cannot be immediately seized by the free molecules surrounding the incandescent gases, free ether exists *between* the molecules—in other words, an inter-molecular condition of free ether exists, as in Fig. 46. This condition lasts only a short time, and there is enormous molecular motion in the spirit molecules during the time the gaseous air molecules are absorbing this free ether.

* It is this violent expansion of molecules in mass which produces the disastrous effects of explosion.

140. To sum up the reactions in our experiment: (Fig. 45) we have rising from the outside the luminous part of the spirit lamp free ether, and gaseous * molecules super-saturated with ether. Ether and the gaseous molecules being "optically empty," we see in the Analyser both rising into the air charged with motes, and giving that beautiful "black steam-like" appearance seen in our experiment. Now, is it possible to sort out or sift out the free ether from the gaseous molecules super-saturated with ether? This experiment is very easy and instructive. Remove the Analyser from the lantern and substitute an ordinary hard glass flask, into which is inserted a loose cork, through which is passed a piece of bent glass tubing. Through the tube we fill the flask with tobacco smoke, thus the flask is filled with brilliantly illuminated white motes. Now put a lighted spirit lamp beneath the flask, and we shall find the glass of the flask acts as a sieve, it excludes the gaseous molecules super-saturated with ether, but allows the free ether to pass through the glass; this latter is quite black. This reaction is seen at the interior and bottom of the glass. The free ether passes amongst the air molecules more quickly than they can absorb it. We thus see this free ether "optically

* It will be noticed the word vapour is omitted in this concept. Vapour is a gaseous atom or molecule when it is super-saturated with ether. It is a true gas when it holds the ratio of ether to external objects—the air molecules. We prefer to use the word super-saturated gaseous atoms or molecules, as it directly expresses the notion.

empty" rising between the gaseous molecules in which the illuminated motes are held suspended. The illustration (Fig. 47) shows the experiment. Again we draw attention to the fact that no description, no illustration, can truly explain the reaction. The simple experiment should be made by the reader and studied.

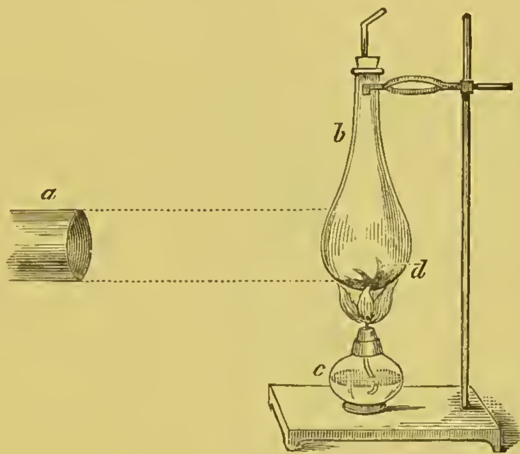

Fig. 47.

a condenser of oxy-hydrogen lamp, *b* flask charged with motes, *c* spirit lamp, *d* free ether (optically empty) passing into the air charged with motes.

141. A similar experiment to that described in paragraph 135 (Fig. 45) is to put the finger in the orifice *a'* (Fig. 12) of the Analyser (charged with motes) instead of the spirit lamp: here we find arising from the sides of the finger, and converging at the tip, a stream of the same black material—gaseous molecules super-saturated with ether, and probably free ether in a very small quantity, the same as comes off from the spirit lamp, but it comes off much more slowly, and therefore rises in a similar

apparently solid form as the air did. (§ 89, Fig. 14). The whole of the body is exuding this "optically empty" material—partly free ether, partly gases super-saturated with ether. It is this exudation, in animals, which tends to keep the skin clean.

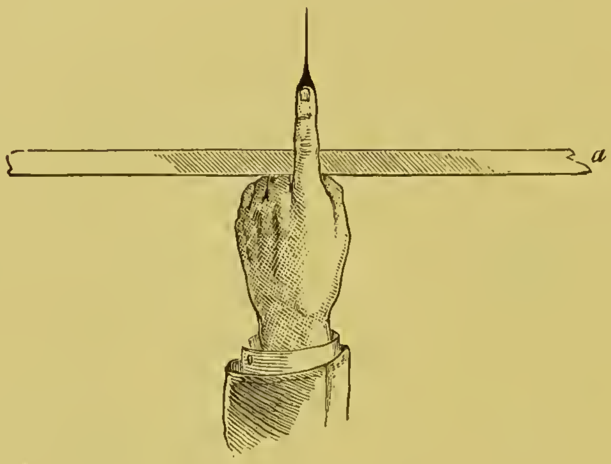

Fig. 48.

Illustration of the "optically empty" fluid coming off the finger as seen in the Analyser charged with illuminated motes: *a* is the bottom of the Analyser.

If the rod, heated or charged with ether as described in § 91, is inserted vertically through the bottom hole of the Analyser as the finger is (Fig. 48), free ether streams off the end of the rod just as the gaseous molecules super-saturated with ether do from the tip of the finger.

142. When there is great difference in dimensions of the free atoms or molecules certain of them become visible.

The mass appears white.* Thus, when the gaseous molecules become considerably enlarged by the absorption of ether or super-saturated with it, and are mixed with molecules relatively under-saturated with ether—that is, very small gaseous molecules—then at least, in one case, they are even large enough to be seen by the naked eye.

Thus, water molecules, when in the condition of steam and mixed with small or cold air molecules, become so enormously expanded that when they are looked at by means of a powerful light, then the super-saturated water-molecules can be distinctly seen! We are all familiar with the fact, when the air is cold we see our breath, when it is hot we cannot see our breath. But the temperature of our body is practically a constant summer and winter, hence the condition of steam from our body is constant, while the external conditions—the air molecules have altered.

142. Whenever a jet of steam is thrown into highly-heated air (that is, air molecules super-saturated with ether) the steam is not seen; on the other hand, if the jet of steam goes into air which is very cold it is distinctly visible in the mass; and the colder it is, the longer it is

* This explains the appearance of the white foam of the sea. The large air molecules become, as it were, trapped in mass between the small water molecules. They, however, quickly rise through and above the water molecules—a species of effervescence.

visible. If on a cold winter's day one goes where there is a beam of sunlight passing into a very cold room, which is dark except for the light given by the beam, and gently breathes into the beam, if the eyesight is good there will be seen the individual expanded molecules of water, or the water molecule super-saturated with ether. We shall investigate this further on.

143. To sum up: All these experiments, which almost wholly appeal directly to our sense of sight, conclusively prove the following facts, which are included in our "Statement of the Case."

> *1.* All gaseous matter consists of elastic spheres or spheroidal entities, called atoms or molecules, which move freely amongst themselves, having every conceivable motion in space as well as a motion of rotation, whilst they have also the power of increasing or decreasing in dimensions in proportion to the ether absorbed. (*See* "Statement of the Case," clauses 1, 3, 4, 5, 8, 15, 16, 17, 18, 19.)
>
> *2.* The fluid—ether, which is probably a compound fluid—normally flows from the earth; it antigravitates. (*See* "Statement of the Case," clause 3.)
>
> *3.* In proportion to the amount of this fluid absorbed by the atom or molecule at any instant of time, so do these entities partake of the antigravitating property of the ether, and thus become lighter. This decrease of weight is so minute as to evade the power of our best

balances, yet the difference is readily seen in the fact that free atoms and molecules (that is, gases and liquids) always rise directly they absorb ether—convection currents. Thus Nature's balances, which require no fulcrum, prove this truth. (*See* "Statement of the Case," clause 3.)

4. The phenomenon called "Heat" consists, therefore, of the reaction of this fluid—ether, on the atom or molecule. It is of a twofold character—First, consisting of the internal pressure (strain) of ether on the atom or molecule, and the quantity of the fluid, ether, held by the atom or molecule: and, Second, the power or potential of the atom or molecule to expand (increase of temperature) and pass on this fluid (conduction and radiation). During these reactions, dimension is the "temperature" of the atom or molecule. (*See* "Statement of the Case," clauses 2, 4, 5, 6.)

5. When the gaseous atoms or molecules chemically unite or become bonded, they expand and then overwrap each other in a concentric manner, and to obtain the result of liquid the atom or molecule contracts, giving out ether, and thus the spherical condition is present in both the gaseous molecule and the liquid molecule. The reaction called "chemical combination" is, in the case of combustion or explosion, to the human mind, an instantaneous one. It follows, when a combination of two or more gaseous objects takes place to form a molecule *of smaller volume*

than the original objects of which the molecule is formed, there is given out very rapidly a definite quantity of free ether. This free ether immediately reacts on the next objects and causes them to expand, and if the conditions are favourable then to combine, and so objects after objects combine to form new molecules. Now if these objects are supplied in their proper order, as we see in an ordinary gas jet, then we have the process going on slowly, and we call it combustion. But if the gases are previously mixed in their proportion to combine, and we only start a few groups of these objects to combine by pressing on them free ether, as we can from free ether arising from the resistance in an electric current (instance, an electric gas lighter), then the free ether resulting from the combination of these few objects is sufficient to combine the residue because more and more, and faster and faster, is the ether let free from the combining molecules, and so this acceleration of the evolution of ether takes place so fast, and with a pressure so great as to produce an almost instantaneous reaction on the whole mass of gaseous objects, and we have enormous reaction attended with great noise, and we call it explosion. (*See* "Statement of the Case," clauses 8, 10, 21.)

6. These concepts eradicate opposing ideas, and get rid of the idea of the repulsion of atoms and molecules—a notion which cannot be grasped; for if atoms

and molecules attract each other, they cannot at the same time repulse each other, so we get the idea that atoms and molecules under external pressure (except when they are in a state of intense vibration) touch each other. The only time when they appear to repulse each other is when they are, momentarily, divided by the fluid ether, and when intense molecular vibration exists (§ 136). (*See* "Statement of the Case," clauses 9, 23.)

7. Clause 11, "Statement of the Case," now becomes a comprehensive concept, and needs no further explanation after the conclusive experiments we have gone through. The illustration given on the screen (§ 117) showing that in the solid condition of matter the molecule does increase and decrease in dimensions according to temperature will readily be seen to apply to whatever conceivable *form* the ultimate entity may exist in, whether angular (crystalline), spherical, or spheroidal.

8. Many atoms and molecules at certain low temperatures, according to their special species, are in their minimum *spherical* condition, and immediately on a further loss of temperature they alter from the spherical conditions and become of some other form—angular; hence, crystallization. If this alteration in form involves a like decrease in the mass, then contraction of the mass follows the contraction of the molecule; but if, during

the alteration in form, molecules in mass do not arrange themselves in so small a compass as in the minimum spheroidal condition, then during the time each entity alters in shape does the contraction of the mass cease or even expansion take place. For instance, solidification of water—ice. *See* Part X., § 180.

Paragraphs 104 and 137 to 140 fully explain the reaction named in the "Statement of Case," clause 21. The whole of these experiments prove the truth of clause 22, "Statement of the Case," and the other clauses, we think, are now self-evident.

VI.

144. In order to fully realise the reaction called Heat, being, as we believe we have proved, the reaction of ether upon the atom or molecule, we shall proceed to experiments showing the order of reactions resulting from alterations of *external* pressure (stress). These operations will not be directly visible to the sight, as in our previous experiments. The apparatus we shall employ will be the exhausting air pump, the thermopile, with the galvanometer (§ 61) and the thermometer. When the thermopile cannot be conveniently used we shall use a thermo-electric pair, or, as it is shortly called, a thermo-pair. The latter apparatus acts in the same way as the thermopile,

but with less power. It consists of a single pair of dissimilar metals. We use either iron and German silver, or iron and platinoid, soldered together. The apparatus is merely two pieces of wire flattened out at the ends, and connected together by soldering. Such a pair is represented in Fig. 49. It is not necessary to solder the pair, tightly twisting one wire round the other is sufficient.

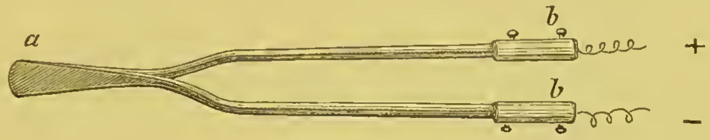

Fig. 49.

The open ends are connected by means of binding screws *b b* and wires with the galvanometer.

Having connected up the pair with the galvanometer, warm the soldered end by placing it between the finger and thumb, and notice the galvanometer. The needle is deflected nearly a quarter of a circle; but if in the same way we warm the open ends by warming the binding screws *b* of the pair, the needle deflects in a like degree to the *opposite* direction. As it is only necessary to use the face of the thermopile, so it is only necessary to use the soldered end *a* of the thermo-electric pair. We shall see, when we study the electric current, that there is good evidence to believe that warming this pair, as it is called, is the flow through the wire of the fluid ether, which comes out of the fingers (§ 141) either as free ether or gases super-saturated with ether, and which we have seen and studied.

145. The first apparatus we shall use is a glass receiver fitted on the plate of the air pump. There is an india-rubber bung fitted in the neck of the receiver, through

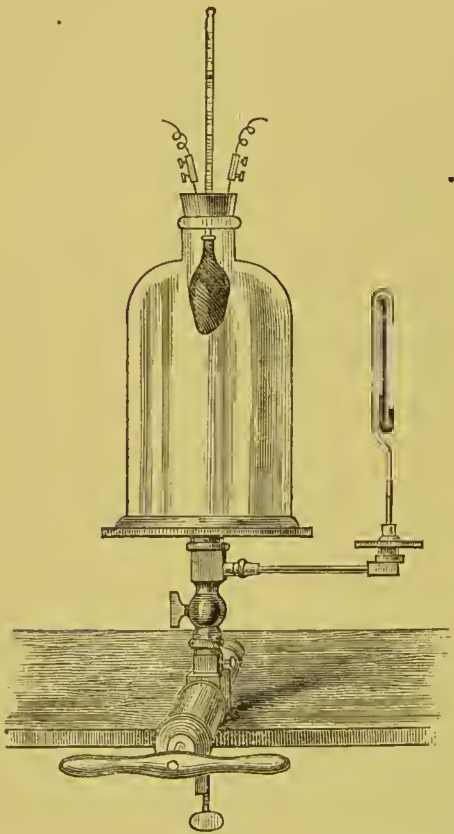

Fig. 50.

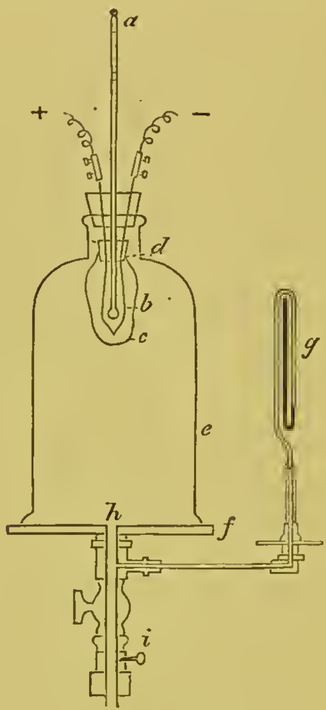

Fig. 51.

Explanation of diagram (Fig. 51).—*a* thermometer, *b* thermo-pair, *c* india-rubber balloon, *d* small india-rubber cork, *e* receiver on plate *f*, of air pump *g* mercury gauge to show the release of pressure on the air molecules, *h* outflow, with stop-cock, through which the air molecules pass, *i* valve to allow the air molecules to re-enter the receiver.

which passes a thermometer and a thermo-electric pair. Both the bulb of the thermometer and the soldered end of the pair are inserted in one of those india-rubber balloons

we have previously referred to (§ 89). The bulb of the thermometer and the soldered end of the thermo-pair are thus hermetically sealed in the balloon, passing through a small india-rubber cork. Fig. 50 represents the apparatus, and Fig. 51 represents a section of the same.

There is a small quantity or number of air molecules in the balloon and the elastic objects—vesicles of ether, of which the air molecules* mainly consist, are thus hermetically sealed inside the balloon; none of them can get out. So also is the contents of the receiver—*i.e.*, between the balloon and the glass—filled with the same objects. We work the pump, and we thus draw out the molecules, or, as it is called, exhaust the air inside the receiver—that is, between the india-rubber balloon and the receiver. The following is the operation:—By means of the valves in the pump we pull out these molecules one after the other. The valves act as traps. How is it these objects come out? Being under the pressure of the atmosphere before we commence the experiment (§ 79), they are all held contracted in dimensions by that pressure, the external pressure being equal in all directions, and as we work the pump and take the molecules out (for they fall through the tube *h*, Fig. 51), the residual ones expand both inside the receiver and inside the india-rubber balloon, and thus they tend to push out the molecules through the tube *h*. We must bear in mind as they go out they take with

* *See* foot note, § 94.

them a certain quantity of the ether which must be replaced. We go on pumping out these elastic spheres—*i.e.*, what is called exhausting the receiver *e*, until nearly all of the air molecules with their contained ether, which existed between the india-rubber balloon and the receiver, are removed. What is the consequence of this reaction? The gaseous entities—the air molecules, inside the

Fig. 52.

balloon expand and distend it until it occupies nearly the whole of the interior of the receiver. Fig. 52 shows the condition of things after exhaustion.

The gauge *g* (Fig. 51) shows now an exhaust equal to a difference of a quarter of an inch in the heights of the mercury. This is as good a so-called vacuum as we can get. Thus during the time the india-rubber balloon is being inflated, and the contained gaseous objects are expand-

ing, causing the india-rubber balloon to expand, the molecules are seizing ether from outside, through the glass of the receiver and the brass plate, through the india-rubber balloon, through the thermo-pair, and through the thermometer, an inflow or radiation of ether through the entire apparatus to replace the ether extracted by the ejected air molecules. If we put a thermopile to touch any part of the glass receiver, we get the reaction of cold; but the thermometer and the thermo-pair with the galvanometer show the reaction in a clear way. In the former the mercury molecules give out ether to the air entities, or "soak out" (as the electricians call the reaction) the ether; they contract, and the instrument registers a fall of 4° Fahr. The galvanometer needle records a marked deflection to cold. If we leave things in this condition for a few minutes, the temperature gets to the condition from which we started the experiment (say 60° Fahr.), and the needle gets to Zero. Obviously if Heat be only molecular motion, as is maintained by the physicist, then the temperature of the thermometer could not go down so long as the india-rubber balloon is distended, for it is the work done by the *internal* air-molecules, which distends it. When the temperature has risen to that with which we commenced the experiment, we unscrew the valve *i* (Fig. 51), and the air molecules rush into the receiver *much more quickly* than we were able to take them out, and now the expanded air molecules in the receiver, through the

increase of pressure, contract, and the india-rubber balloon contracts to the original dimensions, as in Fig. 50, the molecules give out their ether to the apparatus, and we have the inverse order of things. The thermometer then rises 5° Fahr., caused by the mercury molecules "soaking in" the ether and expanding, while the galvanometer registers a reaction of a flow of ether by the needle moving in the direction of Heat. Thus the thermometer receives an excess of ether through the mechanical pressure on the air arising from the molecules rushing into the receiver. This latter is exactly the same experiment as shown in Fire Syringe (§ 134), by which the reaction called Heat was so great as to make German tinder red hot. In these experiments, it may be asked why cannot we get a better exhaust than that registered by the mercury gauge of $\frac{1}{4}$ inch. In other words, why cannot we pull out of the receiver the whole of the air molecules. The reply is, under a given external temperature the molecules have a maximum dimension, and when this dimension is reached, the mutual attractions of the glass and the air-molecules prevent the residue being "pushed out" of the receiver.

146. Now, let us consider: the late Dr. Tyndall illustrated this experiment in his work, "Heat: A Mode of Motion"; but he omits the thermometer and thermo-pair, and is governed in his explanation entirely by observing the inflation of the bladder. This is what he says:—

"According to our present theory, this expansion of "the bladder is produced by the shooting of atomic "projectiles against its interior surface." *

What does the "shooting" of these projectiles mean? These projectiles are described, according to the physicists' views, as almost infinitely minute objects of *constant* dimensions, and their motion, and motion only, which is heterogeneous, is what they call Heat. Hence the greater motion should produce an increase of temperature. We will now take up Clerk Maxwell, and see what he says. Any text book will do, for all physicists follow each other.

"Heat is a form of energy. . . . when a body "is hot it possesses a store of energy, part at least of "which can afterwards be exhibited in the form of visible "work. Now energy is known to us in two forms. One "of these is Kinetic Energy, the energy of motion. ". . . Hence part, at least, of the energy of a hot body "must be energy arising from the motion of its parts, or "kinetic energy. Every hot body, therefore, is in motion. ". . . A gaseous body is supposed to consist of a great "number of molecules moving with great velocity. . . . "When two molecules come within a certain distance of "each other, a mutual action takes place between them, "which may be compared to the collision of two billiard "balls. . . . As the density of the gas increases, the "free path diminishes . . . The hotter a body is, the "more violently are its molecules agitated † (§ 46).

* "Heat: A Mode of Motion" (9th edition), 1892, p. 118.

† "Theory of Heat," revised by Lord Rayleigh (10th edition), 1891, pp. 308 to 314.

Dr. Tyndall gives the concept in the clearest manner:

"In the case of solid bodies, while the force of cohesion "still holds them together, you must conceive a power of "vibration, within certain limits, to be possessed by their "atoms. And the greater the amount of heat imparted to "the body, or the greater the amount of mechanical action "invested in it by percussion, compression, or friction, the "greater will be the rapidity of some, and the wider ampli- "tude of other, atomic oscillations.

"As already indicated, the atoms or molecules thus "vibrating, and ever as it were seeking wider room, urge "each other apart, and thus cause the body of which they "are the constituents to expand in volume. By the force "of cohesion, then, the molecules are held together; by the "force of heat they are pushed asunder; and on the rela- "tion of these two antagonistic powers the aggregation of "the body depends. Every fresh increment of heat pushes "the molecules more widely apart; but the force of cohesion, "like all other known forces, acts more and more feebly as "the distance through which it acts is augmented. As, "therefore, the heat grows strong, its opponent grows weak, "until, finally, the particles are so far loosened from the "thrall of cohesion, as to be at liberty, not only to vibrate "to and fro across a fixed position, but also to roll or glide "around each other. Cohesion is not yet destroyed, but it "is so far modified that the particles, while still offering "resistance to being torn directly asunder, have their lateral "mobility over each other's surfaces secured. *This is the* "*liquid condition of matter.*"

"In the interior of a mass of liquid, the motion of every "molecule is controlled by the molecules which surround it. "But when we develop heat of sufficient power, even "within the body of a liquid, the molecules break the last

"fetters of cohesion, and fly asunder to form bubbles of "vapour. If, moreover, one of the surfaces of the liquid be "quite free, that is to say, uncontrolled either by a liquid or "a solid, it is easy to conceive that some of the vibrating "superficial molecules will be jerked entirely away from the "liquid, and will fly with a certain velocity through space. "*Thus freed from the influence of cohesion, we have matter in* "*the vaporous or gaseous form.* . . . we are to figure "the molecules of a gas as flying in straight lines through "space, impinging like little projectiles upon each other, "and striking against the boundaries of the space they "occupy." *

Now, in every one of the reactions thus explained by the late Dr. Tyndall, the thermometer rises *pro rata* to the so-called molecular motion.

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* "Heat: A Mode of Motion" (9th edition), 1892, pp. 115–118. The reader will readily observe the crux of this quotation hinges upon the meaning of the word "cohesion." "In the case of solid bodies, "while the force of cohesion still holds them" (*i.e.*, the atoms or "molecules) "together, you must conceive a power of vibration. . . . "to be possessed by their atoms." This is a concept a reasonable mind cannot grasp. It is a notion that an atom or molecule is adhering or sticking to an atom or molecule, or *cohering* as it is called, at the same time it is *not* sticking to or cohering, but entity is hitting entity like the motion of two billiard balls, always rectilinear, and the motion is always heterogeneous, an idea which is necessary, to understand the co-efficient of expansion in solids, by increase of temperature; and as temperature with us is never at zero in solid objects, the atoms and molecules of which they are built up are always in heterogeneous motion. This is the physicist's notion of a solid! Try to understand the following of the above quotation, and the mind fails:—In solids, "by the force of cohesion, then, the molecules are held together," but, "as already indicated, the atoms or molecules thus vibrating, and "ever as it were seeking wider room, urge each other apart." Such ideas cannot be grasped; they are practically impossible.

147. The concept of the physicist is: the more the motion, and the greater the volume in mass arising from this motion, the greater is the Heat; and this increase of motion is increase of force—*i.e.*, the air molecules are doing more work as they vibrate farther apart. According to this view, obviously when the india-rubber balloon expands, there is an increase of motion in the molecules—an increase of force—kinetic energy, to expand the balloon; and there should be a corresponding rise in the temperature in the thermometer to correspond with the increase of kinetic energy, because, as Maxwell says:

"Heat passes from one body into another through an "intervening substance, as from a vessel of water through "the glass bulb of a thermometer into the mercury inside "the bulb." *

And this molecular motion, called Heat, is approximately compared to a motion of impact and recoil, like the collision of two billiard balls. Thus the concept clearly is: this impact and recoil of the gaseous molecules causes the molecules of the glass to impact and recoil (when, by-the-bye, the glass should be liquid!); and the glass molecules, in their turn, should knock about, like billiard balls, the molecules of mercury, which should thereby increase in volume. Hence the mercury in our experiment should rise, instead of which *it falls!*

148. Let us consider yet again, when the cubic inch of

* "Theory of Heat" (10th edition), 1891, p. 11.

water was decomposed into its elementary gases (§ 103), it became about 1,800 cubic inches of gas. What is the difference of state as explained by the physicist? Why, in water the atoms are close together, whilst in the gas they are knocking each other about at an enormous rate, and recoiling to a great distance. This motion of impact and recoil, like the collision of billiard balls, "passes from one "body into another through an intervening substance . . . "through the glass bulb of a thermometer into the mercury "inside the bulb," and thus should record a very considerable increase of temperature in the thermometer plunged into the gas. Test this assumed fact: the temperature of the water before it was decomposed was say 60° Fahr., and when we put the thermometer into the gases it is *the same*. Why, according to the kinetic theory, the motion of the gaseous atoms or molecules should be so intense as to cause the motion of the mercury molecules in the bulb to break the bulb! The idea is most extraordinary, because the concept involves the hypothesis that the molecules of the glass bulb should be in greater motion than the mercury molecules; in fact, the glass should be liquid before it sets into relative motion the mercury molecules.*

The situation is utterly absurd, and contradicted by facts; that it is believed in for one moment is a matter of profound astonishment.

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* As a matter of fact, the glass bulb always expands to a very small amount before the mercury molecules rise in the tube of the thermometer.

In the last experiment the thermo-pair and thermometer act in unison. We shall next consider experiments with gases, when these two instruments do not act in unison; in fact, we obtain quite contradictory results.

149. The apparatus we shall now use consists of a double receiver, thermometers, and a thermopile with the galvanometer. It is shown in Fig. 53.

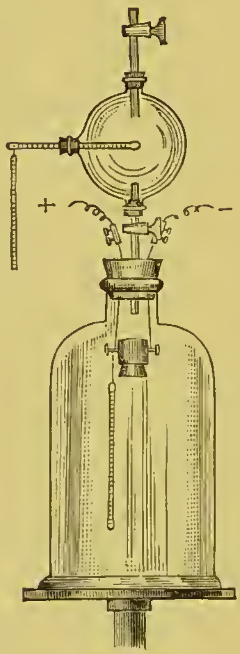

Fig. 53.

The apparatus perhaps will be better understood in section, Fig. 54.

We must note that the face of the thermopile is as far as possible from the outflow *o* of the lower receiver *b*, and very near (one inch) the inflow *n*.

We commence our experiments by repeating the last experiment. We have now no india-rubber balloon. In

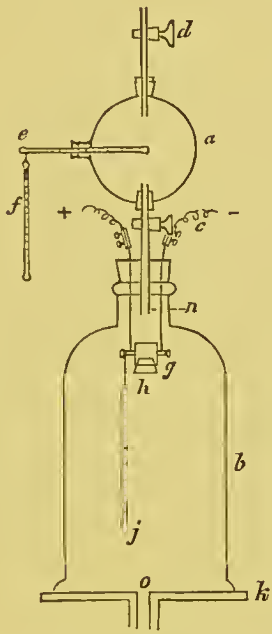

Fig. 54.

a is an upper receiver, connected with a lower receiver *b* by a glass stop-cock *c*. The stop-cock *d* connects the apparatus with the external air—these stop-cocks are inserted by means of india-rubber corks; *e* is a thermometer to show the temperature of the interior of the receiver *a*, passing through an india-rubber cork; *f* is a thermometer to show the temperature of the external air; *g* is a thermopile, plugged at the back with an india-rubber cork *h*, in order to prevent any direct reaction on the back of the thermopile, it is supported by and connected with insulated wires to the galvanometer, they pass through the india-rubber bung in the neck of the receiver *b*; *j* is a thermometer hung on the thermopile to show the temperature of the lower receiver *b*; *k* is the plate of the air pump. The other particulars of the pump are given in Fig. 51. There are thus two ways of allowing air to re-enter the receivers—one by the valve *i* (Fig. 51), the other at the top of the upper receiver *d* (Fig. 54).

this manner we are deprived of seeing the reaction of the expanding of the air molecules, which we were able to do by viewing the expanding of the balloon in the last experiment.

We first of all close the stop-cock *c*, and exhaust the receiver *b*—*i.e.*, we draw the molecules out of the receiver by means of the pump. As we exhaust, the thermometer gradually goes down, and the needle of the galvanometer gradually gives the reaction of cold. We again get an exhaust measuring $\frac{1}{4}$-inch by the mercury gauge *g* (Fig. 51). We let the apparatus remain till the thermometer has recovered itself—*i.e.*, risen to the temperature of the outer thermometer *f*, say 60° Fahr., and the needle of the galvanometer returned to zero. We then open the screw valve *i* (Fig. 51), and the air molecules rush in through the vent in the centre of the plate *o* (Fig. 54), and the reverse reaction takes place—external pressure presses the ether out of the air molecules—vesicles of ether, the thermometer gains this ether,* each mercury molecule expands (*i.e.*, soaks in ether), the mass rises in the tube, and the galvanometer needle gives the reaction of Heat. We again notice, because the air molecules rush in faster than when we take them out or exhaust, there is a difference of a greater rise in temperature than there is a fall in

* To fully understand the details of this reaction, the reader must carefully study the paragraph 113.

exhausting, the latter being a much slower process; the study of the model, explained in § 110, explains the reaction.

Although the thermopile is as far away from the source of the outflow *o* as possible, yet the reaction of both the thermometer and the galvanometer are in unison.

150. Next we will turn off the stop-cock *d*, the stop-cock *c* being already turned off, and we exhaust the lower receiver as before. Here we have precisely the same reaction as in the previous experiment. It is the same experiment.

We allow the thermometer *j* to recover and go to the temperature of the air, 60°, and the needle of the galvanometer to return to zero. The receiver *b* again shows an exhaust equal to $\frac{1}{4}$ inch of the mercury gauge.

Instead of turning on the screw valve *i* (Fig. 51) as we did before, we turn on the stop-cock close to the thermopile *c*, and let the air molecules rush out of the receiver *a* only and impinge upon the face of the thermopile. The rush is a sudden one, and we note the results: the thermometer *j* rises, giving an *increase* of temperature, while the galvanometer needle quickly swings to cold, showing a *decrease* of temperature; it goes as far as it can (90°) to cold, and so violent are the reactions that it strikes against the stop with considerable force.*

* "Now, Joule showed that when air expanded into vacuum, and "consequently did no external work during its expansion, its tempera-"ture was on the whole unaffected"!—"Elementary Treatise on Heat," by Wm. Garnett, M.A. (5th edition), 1889, p. 234. Thus the above experiment contradicts Joule.

Here we have, not only the two instruments refusing to act in unison, but they are acting in opposition.

If Heat were the impact of the gaseous molecules like billiard balls hitting the face of the thermopile, as is the concept of the physicist, here is a condition which should cause the needle of the galvanometer to record Heat in a very marked manner, but instead of that it records cold in a very marked manner!

This is the explanation of the reactions. When the lower receiver *b* is exhausted it is filled with gaseous molecules of greater dimensions than those in the upper receiver, which are of the dimensions of the air molecules of the external air—that is, they are contracted by the pressure of the atmosphere; the larger molecules contain more ether, and the smaller ones less ether. The upper stop-cock *d* remaining closed, and the lower one *c* being suddenly opened, the contracted vesicles of ether rush out of the upper receiver *a*, as they rush out they expand, and while expanding they impinge upon the face of the thermopile so that *during expansion* they seize the ether from the thermopile, which delivers up ether, and a current is thus sent in a contrary direction—the needle of the galvanometer registers cold. Through the intensity of the rush the cold is very considerable, because the air molecules hit the face of the thermopile in rapid succession, and each one at the moment of impact takes its proportion of ether from the thermopile in order to expand. Now, while that process

is going on, the smaller air molecules rushing in from *a* into the midst of the larger ones in *b*, the latter are compressed, they contract and give out ether to the mercury thermometer *j*, which records an increase of temperature. A mean ultimately takes place, and all become the same in dimensions, and the ether is fairly divided amongst the molecules. Nothing can be clearer than the reaction, perfectly in harmony with the proven concepts, but how utterly different it is to the ideas of the physicists!

Let us repeat the experiment. After exhausting the lower receiver we heat the upper receiver by means of a spirit lamp, the Heat radiates through the air molecules—which, being hermetically sealed, remain constant in dimensions, *i.e.*, temperature remains constant, or nearly so—but the thermometer rises, say to 80° Fahr. Now turn on the stop-cock *c*, and the reaction *is still cold to the thermopile and hot to the thermometer j!* Why is this? Because, although the mercury molecules in the thermometer have increased in dimensions (temperature), the vacuum in the stem allowing room for expansion—the air molecules in the receiver *a* are in quite a different condition to the mercury molecules in the thermometer; they are confined in the receiver *a*, and they cannot expand, or only to the small extent resulting from the increased volume of the receiver by being heated. Suppose the thermometer tube and bulb were quite filled with mercury, then if we heated it (the heat being not so intense as to burst the bulb) we could not obtain the reaction of temperature

to any appreciable extent. The receiver *a* is in a like condition. But the air molecules are subject to a considerable internal pressure (strain), § 110, through the considerable flow of ether through them. When we turn on the stop-cock *c*, this strain is released, and the molecules rush out of the receiver *a* into the receiver *b*, as they rush out they are expanding, on contact with the thermopile they absorb ether from it, and we get the reaction of cold. Thus we have the *apparent* reaction of molecules of a relatively high temperature (80° Fahr.) going into the receiver *b*, containing molecules of a lower temperature (60° Fahr.), and producing a reaction of cold, as shown by the galvanometer. Obviously in the above experiment the ratio obtained by the thermometer is false as compared to the temperature in the receiver *a*. The air molecules have barely increased in dimensions, *i.e.*, there is little or no increase in temperature. But we must notice also, when the stop-cock *c* is opened and the air molecules rush out of the upper receiver *a*, the residual air molecules, through the release of pressure expand and absorb ether, a current of ether flows through the entire receiver *a*, including through the mercury thermometer *e*. What is the result? A sudden decrease in dimensions of the mercury molecules—the thermometer, as it is called, falls.

But now, having finished this experiment, that is, increased the volume of the molecules in the receiver *a*, or, in other words, increased the temperature of the molecules, close the stop-cock *c* and open the stop-cock *d*. We shall

then let into the receiver *a*, cold air molecules (registering a temperature of 60° Fahr. as recorded by the thermometer *f*) into molecules of a much higher temperature, as recorded by the thermometer *e*. What is the result? Why, immediately the thermometer *e* rises, showing an apparent rise of temperature of the molecules in the receiver *a*. Obviously the reaction explained by the thermometer is an illusion. Instead of the molecules in the receiver *a*, when the cold air rushes in, increasing in temperature, they are compressed, they decrease in temperature, and it is the loss of ether in the decreasing of temperature which raises the temperature of the glass of the receiver *a*, *including* the thermometer *e*. Thus we have explained the apparently paradoxical reactions of letting hot air go into cold air, and producing the reaction of cold, and of cold air going into hot air and producing the reaction of Heat.

It must be noticed that after the source of increase of temperature is removed from the receiver *a*, that is, after the lighted spirit lamp is removed, yet the thermometer goes on rising to even more than 10 degrees! This is the result of the "soaking out" of ether from the molecules of which the glass is composed.

151. Having allowed all the thermometers to go to the temperature of the room, say 60° Fahr., we alter the experiment by closing the stop-cock *c*, and opening the stop-cock *d*. Again we exhaust the lower receiver, and

get the same reaction as before. After we have exhausted the lower receiver we allow the thermometer to get to the temperature of the external air, and the needle of the galvanometer to get to zero. We will be very quiet while we make this further experiment. We turn on the stop-cock *c*, and let the air rush through the open stop-cock *d* into the receivers, the air molecules impinging upon the thermopile; thus we have the whole pressure of the atmosphere pressing or pushing the air molecules through the stop-cock *d*. Listen to the noise made by the molecules passing the upper stop-cock! The air, soon after the stop-cock] is turned on, whistles sharper and sharper almost a musical note. What does this mean? But now look at the galvanometer needle, it has gone a few degrees to cold, and then immediately swings back nearly 90° to Heat. So here we have two reactions, the galvanometer recording Cold and Heat. On the other hand, if we examine the thermometers, they both record a rise of temperature only.

The reaction denoted by the increasing noise is a very important one; the air molecules not only fill the receivers to the pressure of the external air, that is, the same number of molecules per cubic inch as existed before we exhausted the receivers, but they overreach themselves in the rush into the receivers, and thus the receivers have a much greater number per cubic inch; and this increase of the number of molecules causes an increased external pressure over and above the pressure of the atmosphere on the molecules or vesicles

of ether inside the receiver. This involves the further reaction of giving out ether by the molecules, and the galvanometer and thermometer show the final reaction—the rise of temperature. The reaction is thus explained: as the molecules at first impinge on the thermopile they increase in dimensions, take the ether from it, and it records cold; very soon, however, the excess of pressure begins to be reached; and the inrush of the air molecules press the ether out of those inside the receiver, and thus the thermometer and the thermopile receive it; hence the galvanometer records cold and Heat, while the thermometer records the reaction of Heat only. The increase of the intensity of the whistling noise indicates the increase of intensity of the flow of air.

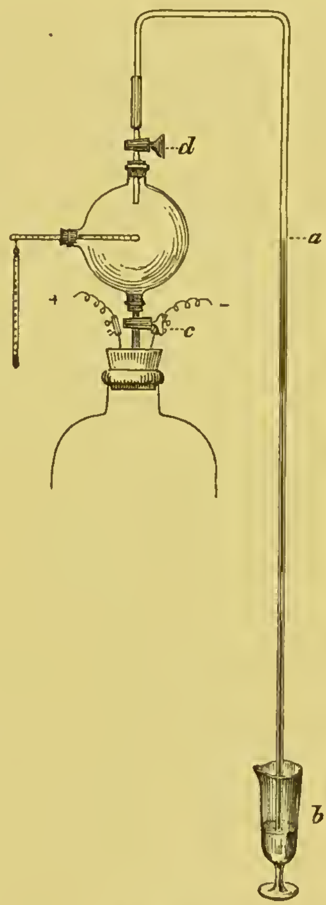

Fig. 55.
Upper portion of double receiver (Fig. 53), with tube containing mercury.

This excess of pressure is easily experimentally shown. Attach to the stop-cock *d* a piece of bent tubing, so as to give a vertical length of about 40 inches. This is done by connecting it with a piece of india-rubber tubing, and we dip the lower end into a vessel containing mercury *b* (Fig. 55).

If we slowly exhaust the receivers, leaving the stop-cocks *c* and *d* open, the external pressure of the air presses the mercury up the tube, and it rises to the position marked *a*. No further working of the pump will cause the mercury to rise higher—we have now got our datum line *a*. We let the air into the receivers, and the mercury in the tube falls to the level of the mercury in the vessel *b*.

Now we alter the experiment by turning off the stop-cock *d*, leaving *c* open. When we have exhausted the receivers to $\frac{1}{4}$ inch mercury gauge, we suddenly turn on the stop-cock *d*, and the mercury rises not only to *a*, but about 5 inches higher. In raising this mercury 5 inches the reaction is attended with considerable work on the part of the air molecules pressing on the surface of the mercury, they have to push up a quantity of a very heavy fluid. On the other hand, if there is no mercury to be raised, then, instead of the small excess of air (say 5 inches of the contents of the tubing) entering into the receivers to compress the air molecules, the air has no work to do except to compress itself, and it enters in considerable quantity.

151a. There is another experiment with this apparatus (without the tube) worth making. Turn off the upper stop-cock *d*, leaving *c* open, and exhaust both receivers to $\frac{1}{4}$ inch by the mercury gauge. After the needle of the galvanometer has gone to zero, we turn on the stop-cock *d*, and we obtain the reaction of Heat only. How can we explain this? The

molecules in both receivers are expanded by the "soaking in" of ether, and when the molecules come out of the upper receiver to impinge upon the thermopile there is no further expansion of the molecules, and only contraction can take place; hence we obtain only the reaction of Heat. In the previous experiment, the current was retarded by the stop-cock *d*, and time was allowed for the galvanometer to record the two reactions of cold and Heat. If, however, we remove the upper receiver, and leave the lower stop-cock *c* in the lower receiver, and then exhaust the lower receiver, and after allowing the needle of the galvanometer to go to zero, we turn on the stop-cock *c*: we get *only* the reaction of Heat, because the reactions of cold and Heat follow each other so quickly that the needle cannot respond, but the needle remains quiet a short time before deflection takes place. The needle, as it were, hesitates. It is important to fully grasp the reactions with this apparatus. Now we venture to assert: no other concept than that which we have given, will explain all these apparently contradictory reactions obtained with this apparatus.

VII.

152. We now pass on to an extremely interesting and instructive experiment, showing that while air looses temperature under certain conditions, the thermometer gains temperature; that is, during the time the air molecules are contracting, the mercury molecules in the thermometer are expanding. Here we have two entirely opposite reactions. The experiment speaks for itself, there is no question as to the facts, and they quite contradict the teaching of the text-books.

Thus Professor Garnett states:

"By heating the bulb" (*i.e.*, of an air thermometer) "in "a bath, whose temperature is measured by a mercurial "thermometer, it will be found that the volume of the air "increases very nearly uniformly *for equal increments of* "*temperature indicated by the mercurial thermometer.*" *

This implies the two instruments act in unison.

The following is the apparatus to test this assertion:

We have here two thermometers—an air thermometer, the bulb *a* with its stem *d*, and the spirit rising in the tube shows the dimensions or temperature of the air molecules in the bulb. The mercurial thermometer *j* shows the ratio of dimensions or temperature of the mercury molecules in its bulb to the dimensions or temperature of the air molecules in the air thermometer.

* "An Elementary Treatise on Heat," by William Garnett, M.A. (5th edition), 1889, p. 89. The italics are Professor Garnett's.

POSTSCRIPT.

Since the work has been printed, the Author sent a copy of the very interesting and important experiment in page 229, § 152, fig. 56, to one of our eminent physicists, who was so interested in it, that he ventured to suggest that the apparently contradictory reactions might arise from the vapour of the spirit of wine in the bulb of the air thermometer. The Author had previously negatived that question by using mercury instead of spirit of wine. Since then he has repeated the experiment, using oil, inserting in the bulb of the air thermometer some chloride of calcium to keep the air perfectly dry. Now, if a heated soldering iron be placed near the top of the bulb so that there is a *downward* radiation of ether, the reactions are not altered. Convection can hardly, therefore, be a necessary factor.

The thermo-electric pair *c*, with the galvanometer, registers the reaction which takes place during the experiment. The apparatus is put into work by the following means:—When

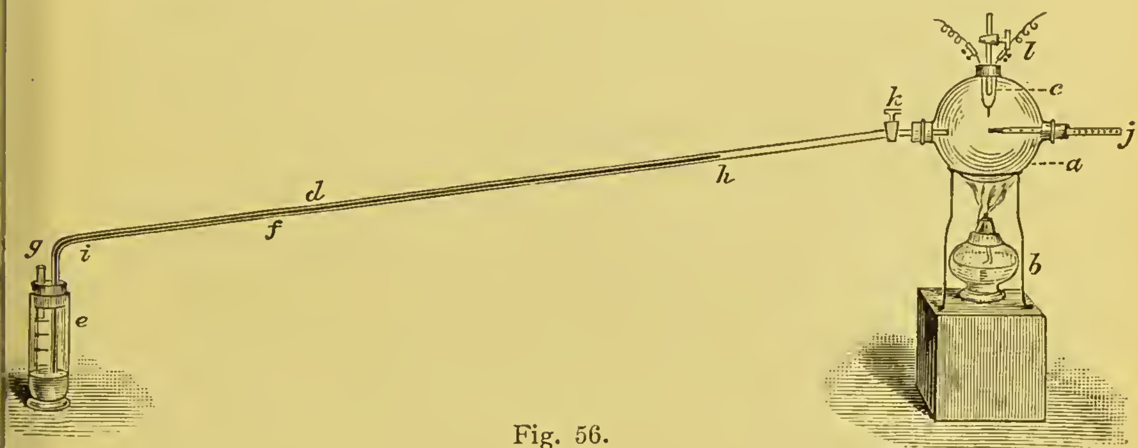

Fig. 56.

a is the bulb of an air thermometer, consisting of a three-way receiver about 3 inches in diameter, into the necks of which there are inserted three perforated india-rubber corks. Through one of these corks is inserted a long piece of glass tubing *d*, 47 inches long, passing through a cork in the neck of the bottle *e*, containing coloured spirits of wine; *g* is a piece of glass tubing to permit the pressure of the air to act on the surface of the spirit. The object of this tube is to prevent excessive evaporation of the fluid; *k* is a glass stop-cock in the tube, and *l* is another glass stop-cock passing through the india-rubber cork. The latter is found to be very convenient when the apparatus is permanently set up, for by turning it on we can allow all the spirit to run from the tube *d* into the bottle *e*, or by it we can regulate the height of the fluid in the tube. Through the upper india-rubber cork there passes a thermo-electric pair *c*, which is connected with the galvanometer. Through the third cork there passes a mercurial thermometer *j*.

it is first put together the coloured spirits in the tube *d* is level with the fluid in the bottle *e*; we turn off *l* and turn on *k*, and put a lighted spirit lamp *b* below the bulb

of the air thermometer, the air molecules expand by the absorption of free ether (§ 140, Fig. 47), they come out of the end of the tube, dipping in the spirit in groups, and we commonly call these groups of molecules air bubbles. Having allowed as many of the air bubbles to escape as is found by experience sufficient, we remove the spirit lamp. The air molecules in the bulb *a*, being now super-saturated with ether, gradually lose the excess of ether; they contract, giving the ether out to the bulb, the mercurial thermometer, and the thermo-electric pair, and as they contract the outside pressure of the air operating through the tube *g* forces up the fluid to follow the contraction of the molecules to *h*. The air thermometer is now at the temperature of the external air. If the apparatus is properly adjusted, the thermometer *j* shows the temperature, say 60° Fahr.,* of the air inside and outside the air thermometer; or, mathematically expressed, the ratio of the dimensions of the mercury molecules to the air molecules is an equation. The spirit having risen to *h* shows this ratio. The air is now hermetically sealed inside the bulb and stem by the spirit in the stem. The rise of the spirit to *h* therefore shows the dimensions of the air molecules, in mass, occupying the bulb of the air thermometer, or, otherwise expressed, the temperature of the air in the air thermometer. Our apparatus is now in working order.

* Of course any other temperature can be taken; the experiment works out the same.

We proceed to the experiment: we put the lighted spirit lamp *b* beneath the bulb of the air thermometer *a*. The air molecules inside the bulb begin to immediately absorb the free ether rising from the spirit lamp (§ 140) they expand, and force or push the fluid back into the bottle until it reaches the point *i*. The very instant the liquid reaches this point, the spirit lamp is quickly removed. We carefully notice what has taken place. The mercury thermometer *j* has risen from 60° to 65° Fahr. The galvanometer needle has moved in the direction of Heat in a like ratio. But now see what is going on! For a few moments the gaseous entities inside the air thermometer do not give evidence of contraction, but only evidence of intense molecular motion (§ 80, *5*): this is seen by the fact that the liquid at *i* is alternately and quickly rising and falling, not to a very great extent, an oscillation giving evidence of vibration (§ 114) of the air entities. But what is the mercurial thermometer doing all the time the liquid in the stem of the air thermometer ceases to rise, or while the temperature remains constant? Why, the molecules of mercury are gradually expanding, and their volume registers 70°. Now there comes in a new reaction in the air thermometer—the liquid gradually rises—the air entities in the air thermometer are contracting, and as they contract and give out the ether, the mercury molecules keep on seizing this ether (in common with the other parts of the apparatus), we can *only* see the reaction in the thermometer, and on the thermo pair. In the former it now

records 80° Fahr., the galvanometer needle has gone towards Heat in a like ratio! During this reaction the air in the bulb of the air thermometer has contracted to the point *f*. Thus the air thermometer goes down as the mercury thermometer goes up! In other words, the air molecules contract, whilst the mercury molecules expand. So instead of the temperature of the air in an air thermometer, as measured by a mercurial thermometer, being, as Garnett says, very nearly uniform "*for equal* "*increments of temperature indicated by the mercurial thermo-* "*meter*,"* the ratio of difference of temperature is inverse, and inverse to a considerable amount—a rise of 15° Fahr. for a considerable decrease of temperature of the air. We must remember that we only raised the temperature of the air thermometer 5° Fahr., as shown by the mercury thermometer. When, however, the air thermometer records the point *f*, and the mercury thermometer has risen to 80° Fahr., the observations of the physicist seem perfectly harmonious, for both the thermometers fall—the molecules in the air thermometer contract in a like ratio to the molecules in the mercurial thermometer. It must be noticed that before this reaction of the fall of temperature of the mercurial thermometer commences, it remains for a short time at 80° Fahr., during which time the air thermometer is slowly and steadily falling. This is again an inverse process.

* The italics, as we have stated, are Professor Garnett's.

153. If the kinetic theory were wholly true, then Garnett's statement would be correct—namely, as the air molecules in the air thermometer decreased in motion, the mercury thermometer would fall; and, inversely, as the air molecules in the air thermometer increased in motion, the mercury thermometer would rise (§ 50). The experiment, however, wholly contradicts this view. In explaining this experiment, we have endeavoured to convey to the mind the true reaction, but there is something more to explain. The initial reaction, we must keep in mind, is the swelling or "soaking in" of ether by the air molecules in the air thermometer through the evolution of ether from the spirit lamp (§ 128 to 130, and § 140). Here not only do the air molecules expand by the absorption of ether, but the ether rises upwards and the molecules are rising charged with this ether, causing the so-called convection currents. Thus we have three reactions: 1st, the swelling of the air molecules; 2nd, the radiation or passage ot ether *through* them (§ 110); and 3rd, the molecular motion produced by their rising, those which receive the most ether tending to get to the top of the bulb. The glass of the bulb with the thermo-electric pair and the mercury molecules in the mercury thermometer absorb this free ether as the air molecules give the ether up to them, and the latter are then contracting and falling towards the fresh free ether given off from the bottom of the bulb. The heated glass at the bottom of the bulb of the air thermometer gives out the ether some time after the lamp

is removed. In the mercury thermometer—each mercury molecule receives an amount of free ether; each expands, then passes the ether to the glass molecules of which the thermometer stem is constructed, and from thence the ether escapes into the air. This swelling is the same which takes place in a current of the so-called electrical fluid, the conductor always expands in proportion to the intensity of the flow of the fluid ether. This is the so-called "soaking in" of the electrical engineers. An ordinary incandescent lamp shows this reaction. If this were not so, that is if the molecules only absorbed or "soaked in" ether, and did not also pass on this fluid, then in our experiment the mercury molecules would expand to such an extent as to burst the thermometer. The reaction is explained in § 110, whilst the reaction causing the evolution of free ether arising from the spirit lamp is seen and explained in § 140.

When the molecules in the air thermometer contract simultaneously with the molecules in the mercury thermometer, then the simultaneous ejection of ether, or, as the electricians call the phenomenon, the "soaking out," takes place. This goes on in both instruments, but in different ratios, until the ratio of dimensions of the molecules in the air and mercury thermometers is the same as when we commenced the experiment. The cycle of phenomena is then complete.

154. To fully appreciate the great increase of dimensions of the mercury molecules, or the temperature of the

mercury thermometer, we must remember that the empty part of the stem of the thermometer (if it is a good one) is *at ordinary temperature* a vacuum, hence there is no opposing force to the expansion of the molecules.*

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* Now physicists contradict this view by stating that the apparent empty tube at ordinary temperature contains the vapour or gas of mercury, as also it does in a barometer. The author was much perplexed about this assertion of the scientists, and he had grave doubts about the truth of such a statement. He consulted an experienced barometer maker, and was informed by him that he (the barometer maker) felt confident that a well-made barometer had a perfect vacuum; and so, in like manner, the contents of the empty tube of a thermometer is a true vacuum. On looking over the stock of the barometer maker, the author saw two barometers of a special make—the end of the barometer tube was contracted to a fine bore, and this contracted glass tube reached upwards to the same height as the barometer, so that there was a long U tube—the left hand arm was closed and nearly filled with mercury; the right hand, which was narrow, open and nearly filled with coloured glycerine. Now, with this apparatus the very slightest movement of the mercury showed a very considerable increase in the height of the glycerine in the fine tube, so much so that a difference of 1 inch in the mercury tube registered a difference of 7 inches in the glycerine tube. The barometer tube was fully exposed, so that one could put one's hand on the empty part of the tube where the so-called Torricellian vacuum existed. Now if there were vapour or gas of mercury in this apparently empty space, it should expand from the heat of the hand and press down the mercury, and thereby cause the glycerine to rise. The author tested the reaction; in the one instrument he obtained a rise of the glycerine of ¼ inch only, the other instrument showed no movement whatever, and he remarked that "in the first instrument there "was a little air." "Oh," said the barometer maker, "we can soon "ascertain that"; and he tilted up the instrument, caused the quicksilver to ascend to fill the tube, and there was the tiny bubble of compressed air floating on the top. Now this experiment shows either the vapour or gas of mercury differs from all other known vapours and gases, if it exists in the apparently empty part of the tube, or else there

155. Yet again there is another reaction to understand in our experiment. When the air molecules inside the air thermometer are extended to their just dimensions

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is no vapour or gas in the Torricellian vacuum at ordinary temperature. The author thinks, with the barometer maker, the latter is true.

If, however, we had sufficiently heated the mercury, so that each atom seized sufficient ether to change into the vaporous condition, then the Torricellian vacuum would cease to exist, and the empty part of the tube would be filled with the vapour of mercury, and if that vapour were still further charged with ether or heated, then the liquid mercury would be forced down. The following important experiment by Mr. William Crooks, F.R.S., in a beautiful manner tends to prove this.*

"THE DARK SPACE IN MERCURY VAPOUR.

"I have found, however, the phenomena of the dark space, &c., "to occur in the vapour of mercury, which is a monatomic gas. This "important result induced me to patiently investigate this subject, and

Fig. 57.

"the result of one experiment is before you" (Fig. 57). "The tube is fur- "nished with aluminium terminals, and is so arranged that the induc- "tion spark can be kept passing during exhaustion to drive off occluded "gases. When at the highest attainable vacuum, the tube is filled with "pure mercury by simply raising a reservoir. On applying heat the "entire contents of the tube are boiled away and pass down the fall

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* "The Chemical News," March 6th, 1891.

by the absorption of so much ether from the spirit lamp, so as to make a difference of 5° Fahr. in the mercury thermometer, then directly we remove the lamp the air molecules in the bulb of the air thermometer instantly commence to decrease in dimensions, and external pressure upon the individual molecules is released, thus giving play for each molecule to vibrate by a series of alternate expansion and contraction of each entity *per se* (§ 114). This vibration of the molecule *per se* caused the molecule to impact against molecule, and thus we obtain in a secondary manner the concept of the physicist, for the molecules indeed hit each other with collisions like the mutual reaction of billiard balls. It is during that time

"tubes of the pump, exhaustion going on at the same time. When the "whole of the mercury has thus been boiled away *in vacuo*, except a "little condensed at the upper part of the tube, the results on passing "the spark are as followed:—When the tube is cold the induction cur- "rent refuses to pass; on gently heating with a gas burner the current "passes, and the dark space is distinctly visible. Continuing the heat "so as to volatilise the drops of mercury condensed on the sides, the "whole tube becomes filled with a green phosphorescent light, the "dark space gets smaller and smaller, and ultimately the negative "pole becomes covered with a luminous glow. On allowing the tube "to cool, the same phenomena ensue in inverse order. The luminous "halo expands, showing the dark space between it and the pole, and "this dark space gradually grows larger as the tube becomes cooler. "The mercury again condenses on the side of the tube, the green "phosphorescence grows paler and paler, until at last the induction "spark from the large coil refuses to pass."

Since this was written, Professor Dewar has produced a vacuum so completely devoid of molecules in the gaseous form, that ether would not pass, or but sparingly pass, the vacuous space. (Lecture, Royal Institution, January 20th, 1893.)

we have alternate rising and falling of the liquid at the point *i*, which oscillation gradually decreases as the fluid rises in the tube and the reaction becomes steady.

156. Now, if the stop-cock *k* (Fig. 56) be turned off, when the spirit lamp is removed that is, when the spirit stands at *i*, and thus left till the mercury thermometer again registers 60° Fahr., that is, the temperature of the external air, the reactions in the bulb of the air thermometer are not quite the same as if the tap were kept open, but the reactions on the mercury thermometer and the thermo-electric pair remain the same. The molecules in the bulb do not contract as they do when the spirit rises; they remain larger in dimensions than they were before we put the spirit lamp to the bulb. Now the ratios completely fail, and this is proven by the fact that directly we turn on the tap and allow the liquid to suddenly rise in the tube, the galvanometer gives a sudden reaction of increase of temperature equal to 4°, and there is a fraction of a degree in the rise of the thermometer. This is the experiment of the fire syringe repeated in a very delicate manner (§ 134). The fluid rises 40 inches in the tube, taking up 20 cubic centimetres of fluid, and with this small amount of contraction of the air molecules by the pressure of the fluid we obtain a distinct reaction of 4° deflection to Heat, as registered by the needle of the galvanometer.

157. A very familiar way of showing these interesting reactions is illustrated thus: In a hot bath, when we move

our hands in the hot fluid, we find the hand gets what is called an increase of Heat. The hand feels hotter while it is in motion in the hot water than when it is still. Our sensations do not deceive us, as the hand passes through the hot water, the water molecules give out their ether to it as it passes from molecule to molecule, and the hand receives the ether more quickly, or more generally expressed, becomes heated more quickly than it would if kept still in the liquid. Just the same with the thermometer—if it is moved about in the hot water, it will rise more quickly than if it is kept quiet in one position in the water. The difference between this illustration and the experiment just explained is an inverse process, for in the illustration the thermometer moves in the water, in the experiment the thermometer is stationary, whilst the air molecules quickly rise and impinge on the thermometer; this process is the convection current of the physicist.

In these experiments with this apparatus we find these concepts confirmed: There is a finer atomic fluid than is known to the chemist or physicist called ether, that the dimensions of the atom and molecule differ according to the fluid contained in the object at a given moment of time, and that this dimension of the atom or molecule is called the temperature of the atom or molecule. Can the kinetic theorist equally well explain the reactions? We, without hesitation, venture to say he cannot.

VIII.

158. We now proceed to explain a very simple, but at the same time a very instructive experiment. The apparatus consists of a glass U tube with a bulb, as figured in Fig. 58.

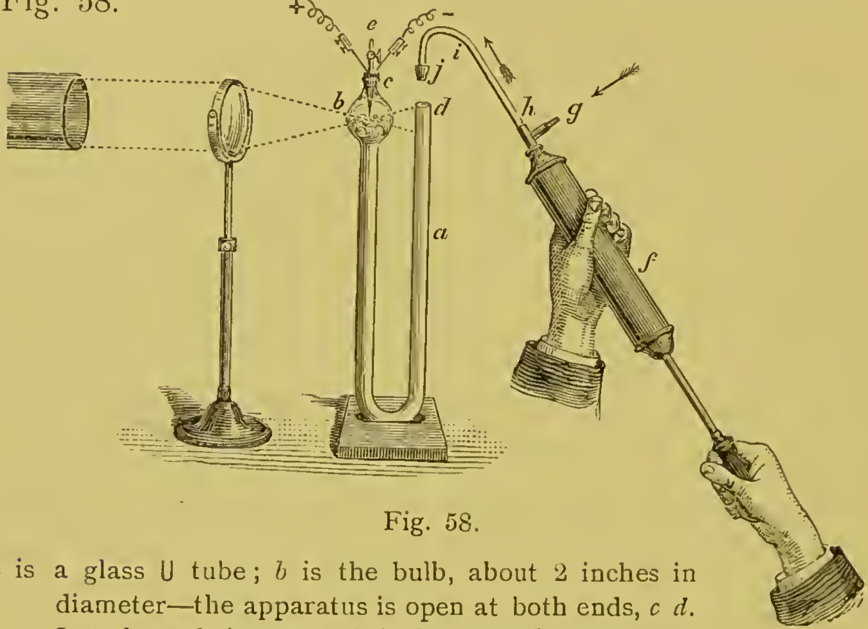

Fig. 58.

a is a glass U tube; *b* is the bulb, about 2 inches in diameter—the apparatus is open at both ends, *c d*. Into the end *c* is put a tightly-fitting perforated india-rubber cork, through which is passed a glass stop-cock *e*; and also there is drawn through the cork a thermo-electric pair, which is connected with the galvanometer. The second piece of apparatus consists of a two-way force pump *f*, having an inflow at *g* and an outflow at *h*. The inflow and outflow are protected by valves, so that when the pump is in work there is a current of air, which flows in the direction of the arrows. To this pump is attached a piece of thick india-rubber tubing *i*, connected by means of a short piece of glass tubing which passes through a perforated india-rubber cork *j*. This cork fits tightly the orifice of the open end of the U tube *d*. The third piece of apparatus is the oxy-hydrogen lamp, giving parallel rays, which are converged by means of a lens on the bulb of the tube *b*. This bulb, therefore, is brilliantly illuminated. At present nothing is seen in the bulb, it is filled with the molecules of the air, exactly under the same condition as the invisible air, outside the bulb.

159. We proceed with the experiment thus: The stop-cock e is turned off. The india-rubber cork j is firmly inserted in the open tube d. We now work the force pump f, and thereby air is forced into the U tube and bulb b. We go on pumping, and thus forcing more and more molecules into the bulb, and the needle of the galvanometer shows the reaction of Heat. This result ensues because we keep on pressing more and more of these vesicles of ether into the tube, and we thereby force the ether out of those vesicles—the air molecules, which are already in the bulb. The glass bulb thus becomes super-saturated with ether—that is, warmed—but the only part which shows the reaction is the thermo-electric pair by means of the galvanometer. Well then, we have crowded a considerable number of molecules into the bulb, now contracted by pressure, and as they increase in number and decrease in dimensions, so do we put an internal stress; in the ratio to this stress there is a strain arising through the desire of these atoms and molecules to expand to their normal dimensions. Presently, a time arrives when the internal pressure becomes so great as to exceed the resistance of the cork j, which suddenly bursts out (as shown in the Fig. 58), and immediately the bulb b is filled with a cloud of molecules, the molecules *descend* like very fine rain. This cloud quickly disappears, being again absorbed by the air in the bulb. At the moment the cork bursts out, and the pressure (stress) released, there is no sudden reaction, as we might expect, in the galvanometer. How is this? Here

comes in, perhaps, one of the most beautiful illustrations of the concept we have received. Mark, during the whole time we were pressing together the air molecules, no reaction was visible in the bulb—it remained perfectly transparent. Gases and vapours consist of hollow elastic spheres filled with ether; as we compress these spheres they become nearly equally reduced in volume. But the instant pressure is released, the molecules expand *unequally*. Some molecules expand and absorb ether at the expense of other molecules. What is the consequence? Why, those which expand at first seize the ether from the molecules which are not strong enough or favourably placed to resist the sudden seizure of the ether; the latter contract and become what the physicists call denser, *i.e.*, heavier. Those which lose ether become, for the moment, so decreased in volume as to assume the liquid condition; these small molecules group themselves into groups, they are minute drops of liquid; these drops form the cloud which is seen—they immediately commence to gravitate and to fall as rain, but no sooner do they begin to fall than the pressure, having become normal, they again resume the gaseous condition, they expand to the dimensions of the molecules of which the outside air consists. Hence the cloud disappears. Now these groups of liquid molecules can be seen with proper apparatus by means of the microscope, and the objects look like Fig. 70. There is, however, a great difference between these groups of molecules and the objects seen in Fig. 70: the latter *rise*,

whereas those seen in this experiment *fall or gravitate*, and then they disappear. Here see if we can understand one great fundamental law. Whenever there is marked difference in dimensions of molecules, then either the larger *single* molecules become visible or the smaller liquid molecules *in groups* become visible. We shall in our next chapter show the former. Thus in this experiment the groups of denser and very much smaller entities become visible.

160. Let us analyse this experiment. As we pressed in air by means of the force pump, we tested air in its normal condition. But we know air consists of oxygen, nitrogen and water in the gaseous form, motes and germs of many sorts; in fact, it is a highly complex mixture. We attach to the nozzle of the force pump at the inflow *g* (Fig. 58) a piece of india-rubber tubing, which is connected with two vessels, one tightly packed with cotton wool, the other filled with calcium chloride (Fig. 59). The object of the cotton wool is to filter motes from the air; the calcium chloride dries the air, *i.e.*, abstracts the water molecules in the form of gas from the oxygen and nitrogen molecules.

First, when we work the pump, we will draw the air through this cotton wool only, *i.e.*, through the tube *b*. We thus pass into the U tube filtered air, *i.e.*, air devoid of motes. We turn on the stop-cock *c* (Fig. 58), and pass a quantity of the filtered air through the U tube; by this means we clear the air of motes in the bulb and tube. Having sufficiently done this, we turn off the stop-cock *c*,

and repeat the experiment in clause 159. We get the same result. Obviously the motes are not the factors in the case.

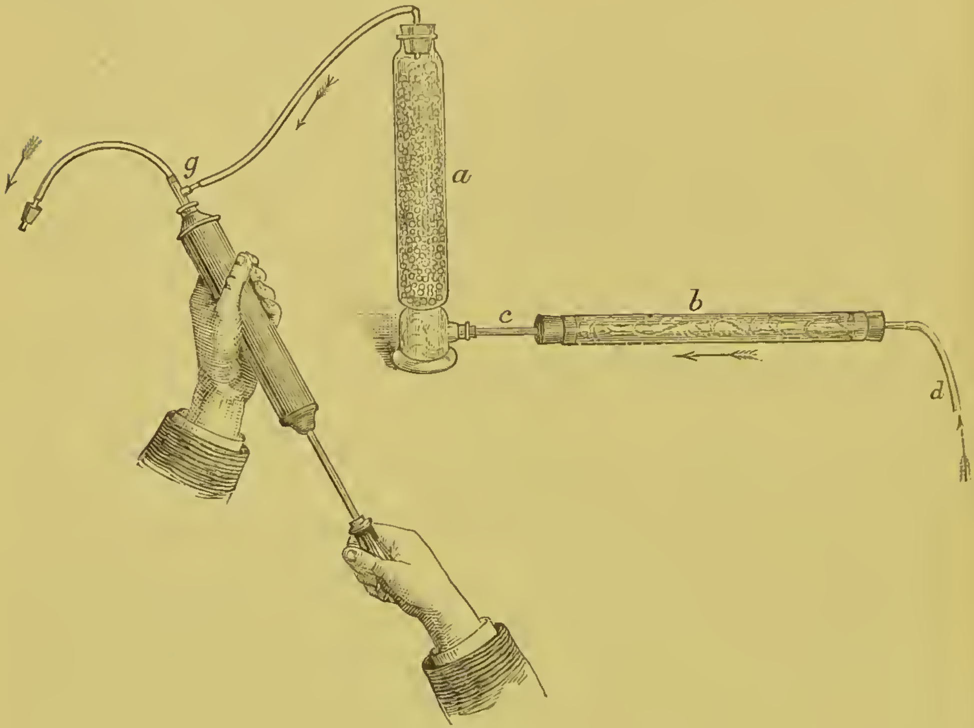

Fig. 59.

a is a vessel containing chloride of calcium, having an india-rubber tubing connection to fit on the inflow of the force pump at *g*; *b* is a glass tube filled with cotton wool, and connected with *a* by means of india-rubber tubing at *c*. The two pieces of the apparatus can be disconnected so that the air can be drawn through *a* without going through *b*, or *b* can be fitted directly to the force pump and used independently of *a*. There is a piece of india-rubber tubing at *d* to affix to a vessel holding any special class of gas to be tested. Of course, when this is open, only air is tested.

161. We next pass the air through the vessel with chloride of calcium *a*. Now chloride of calcium has a great affinity for water, and as we draw the air through this

material, it seizes the water molecules and keeps them back. We are now able to charge the U tube with air holding fewer motes (the chloride of calcium attracts some of the motes), and almost free of water molecules. We cleanse the U tube by turning on the stop-cock *e* (Fig. 58) as before, and having sufficiently effected this, we turn it off and repeat the experiment. We now obtain a different result. We have lost a large amount of the cloud; it is not so brilliant, and it does not tend to gravitate to such an extent. The difference is quite marked. Obviously, therefore, the water molecule is a factor, and assists in causing the cloud.

162. We connect *d* (Fig. 59) with the gas jet, and *a* with the force pump; thus the gas goes through *b*, and any motes are separated, and then through *a*, where any water molecules are absorbed. Now dry gas devoid of motes is supplied to the force pump. Having cleansed the U tube as before, we now force this gas into our apparatus. The cork bursts out, and we obtain the same result as the last experiment—a much smaller and less marked cloud.

163. Here is a steel cylinder containing compressed oxygen gas. We attach a brass stop-cock to one of those india-rubber balloons we before used (Fig. 13). We let a little gas into the balloon and press it out again a few times; thus we clear the balloon of air, and now we fill the balloon with the oxygen gas, and it expands so that

we have nearly a cubic foot of gas in it. Attach the balloon to our apparatus *d* (Fig. 59), and turn on the tap. When we bring the force pump into action we press the pure oxygen into the U tube; we cleanse it, and we repeat the experiment as before. Again we obtain the same result—a cloud, but not clearly so well defined as with the normal air. These clouds are formed in all the experiments, the difference only being: air charged with water molecules produces a denser cloud. When the gases are dry and devoid of motes the cloud disappears very much more quickly; in fact, if the gases are quite pure, the appearance and disappearance of the cloud is almost instantaneous—still it exists.

164. Let us see if we can convey to our minds an idea of this complex condition of things.

The liquid entity, the molecule, is a sphere very minute, to our minds infinitely minute, sparingly compressible. The gaseous or vaporous entity is a sphere or spheroid, highly elastic, and containing much of this fluid ether. Such contained quantity may be called latent ether. Now in spheroidal bodies Nature never packs them as a mass in their minimum volume. Take a measure of spheroidal seeds, say a quart, we strike the measure so as to measure an exact quart. Commence to gently shake the measure, and the seeds begin to get closer together, so we soon find we have less than a quart of seeds. Take a large glass measure and fill it with glass marbles; note how irregularly the marbles are packed.

When we shook the seeds to a smaller volume the mass assumed a denser condition. A very important illustration of this fact is shown in the water hammer (§ 206). Simple as this illustration is, it is an important factor in our experiments, for notice: When the molecules are irregularly placed, certain of them have more contact and more external pressure than others. We take the case of the pure oxygen gas. When the bulb is filled with the gas at the pressure of the air, or as it is called a pressure of one atmosphere, it consists of vesicles of ether of the same dimensions as the air molecules, but not packed in the

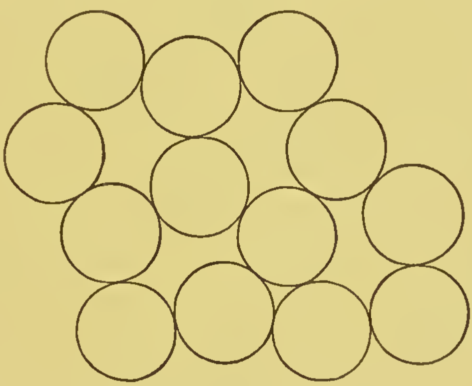

Fig. 60.

densest condition. A diagram will now assist us. Let the circles in Fig. 60 represent sections of the gaseous molecules at the pressure of the atmosphere.

Notice here the molecules are not placed in the smallest compass. When we press more molecules into the bulb, they are placed in the same relative conditions, but become smaller, and the ether is pressed out of them as

they enter the bulb (diagram Fig. 61 very roughly represents the state of things), thereby warming or charging the glass bulb with ether in common with the thermo-pair. But note again, as we keep on pressing in the oxygen molecules, they all remain fairly uniform in dimensions but irregularly placed, and each molecule is smaller *pro rata* to the pressure. So long as this condition continues the gas entities remain perfectly clear; they are, as Tyndall calls them, "optically empty." Now the result of the irregular condition of the molecules produces the effect that some have a greater stress upon them than others. What is the result from this? Why, directly we release the pressure by the bursting out of the cork, those which have the least contact, and consequently the least pressure, have the start in their power to expand, and they begin to expand at the expense of the molecules which are less favourably situated, and thus having the start of absorbing ether, they commence to expand at the expense of those which have the worst chance; the result is, the former increase in volume by the gain of ether, the latter decrease in volume by the loss of ether; an enormous difference in dimensions *for the moment* takes place. The small molecules decrease to such an extent that they become for the moment in a liquid condition, they form themselves into groups and thus form minute masses of liquid oxygen gas, and these groups are visible in the mass and form the clouds. But the greater part of the reaction

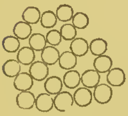

Fig. 61.

takes place in the bulb; hence the reaction is there seen to the greatest advantage. The reactions, therefore, are an interchange of giving and taking of ether, and consequently a swelling and contracting amongst themselves. It follows, therefore, the reaction here on the thermo-electric pair is almost *nil*, not sufficient to move the needle of the galvanometer. The condition of the molecules when the cloud exists, may be illustrated by the diagram, Fig. 62. The groups of small contracted vesicles

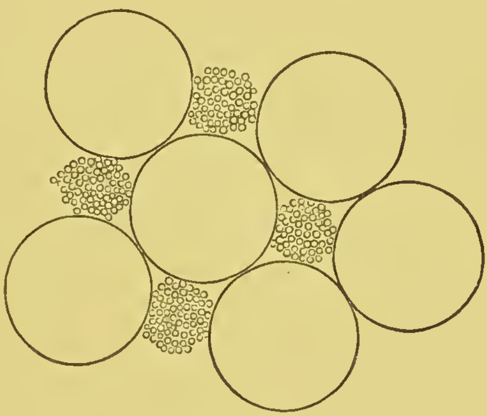

Fig. 62.

of ether may represent the liquid condition which is seen, and the large spheres the gaseous condition of the oxygen molecules, or molecules super-saturated with ether, which are not visible in the experiment.

When dealing with steam, we shall presently see what a marvellous revelation to the eye this concept brings forth.

165. In our first experiment the conditions were very different to the experiment with dry, pure oxygen gas.

We operated with nitrogen and oxygen molecules, and with molecules of water gas, motes, and other matter, and we had not only the reaction of oxygen and nitrogen gases, but plus the reaction caused by the water molecules and the motes. The water molecules were first to lose the gaseous form and became groups of water in the liquid condition which was aided by the motes as centres of attraction. This fact Mr. Aitken has demonstrated, because he has found if we saturated air with water gas so as to hold as much as it can of this gas, then the greater number of motes there are, the greater the number of groups of water molecules in the form of liquid—hence he has been able approximately to count the number of motes in a given volume of air by counting the groups of water molecules which fall upon a prepared plate as minute drops of rain. It is not certain, however, if the motes are wholly the centres of attraction, because there are known to be other things besides motes in the gases of which the air consists—germs are well known to exist and they also may be centres of attraction, hence Mr. Aitken may not only count motes but germs and motes by his process.

166. We must now direct our attention to another way of shewing these experiments. We press the air or gases into the U tube, but before we do so we very firmly press the cork *j* (Fig. 58) into the mouth of the tube *d*, or, better, tie it in by means of a fine string so that it cannot burst out. Having got sufficient pressure on, we suddenly turn on the stop-cock *e*; we get the same cloud and the

same reactions as before, but in a more marked manner. Now we have a sudden outflow of molecules. The molecules not only here have the reaction of expansion and contraction, but there is a sudden expansion of them as they pass through the stop-cock near the thermo-electric pair. At this point they absorb heat from the thermo-electric pair, and we have the reaction of cold shown by the needle of the galvanometer, which, instead of being stationary as in the previous experiments, shows a marked deflection to cold.

We may here ask the kinetic theorists to give their complete explanation of these reactions, and they must fail.

IX.

167. The next experiments will be with liquids, and we shall select for our purpose that well-known liquid—water. Before we commence we have again recourse to our Analyser (Fig. 12). It is now charged with motes, and illuminated with the intense light from the oxy-hydrogen lamp. We remove the cork *a*, and put into the hole a test tube partly filled with water. Also we remove the lower cork *a'*, and insert the small lighted spirit lamp (Fig. 45). We again observe the reactions from the spirit lamp, as explained in § 136.

The following illustrates the experiment:—

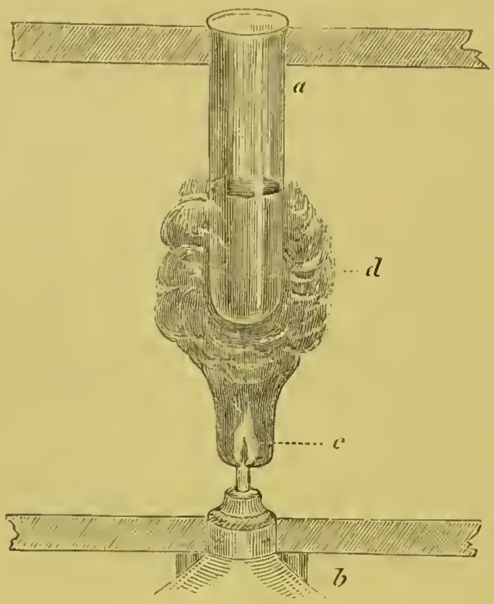

Fig. 63.

Where *a* is the test tube partly filled with water; *b* is the lighted spirit lamp; *c* is the flame; *d* is the "optically empty" gases super-saturated with ether, with the free ether arising amongst them (Fig. 46).

The water in the test tube consists of very minute spheres (§ § 96 to 98). These spheres do not quickly absorb the free ether, but take up minute quantities of it, molecule after molecule, and thereby cause those which receive the ether to rise in the fluid. Thus are created the well-known "convection currents"; this term has been merely a statement of fact—wholly unexplained. We cannot proceed far with this experiment because the lamp speedily consumes the oxygen in the Analyser and goes out. The object of the experiment is merely to associate the reactions in the mind, so that when we make the

experiment in air, not charged with motes, we know we have still this invisible compound material being given off and surrounding the vessel of water. Indeed, we must keep in our minds the fact that every heated piece of matter is giving off this fluid ether, and that every result of combustion gives off this invisible compound fluid in great quantities. Let us consider an illustration. We have here an ordinary lighted Argand gas burner with its glass chimney. We put a piece of wood over the chimney, it becomes incandescent and bursts into flame. It is not the *flame* from the Argand lamp which lights the wood, but the free invisible ether which attacks the wood. It is the ether which lights the wood. If we were to look at the upper part of this chimney in air charged with motes and brilliantly illuminated, this is what we would see

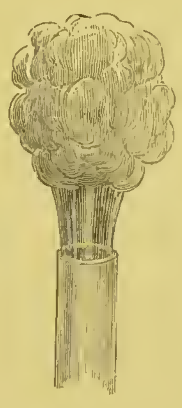

Fig. 64.

(Fig. 64)—an enormous evolution of what looks like black steam arising from the chimney, just as we see from the spirit lamp (Fig. 45). This black fluid, however, is a

mixed "optically empty" material, consisting of gaseous molecules super-saturated with ether and free ether. If we were to take a hot poker and view it under like conditions we saw the hot rod (§ 91) we could then see the free ether ascending out of and from the poker. We must thoroughly saturate our minds with this fact, and not believe the experiments are mere exceptions.

168. To continue, we take a beaker nearly filled with water, and into it we put some material a very little heavier than the water—fine saw-dust does very well. Beneath the beaker we place a lighted spirit lamp (Fig. 65). Almost immediately the so-called "convection currents" commence. What are they?

We noted in § 136 that the black material coming off the spirit lamp consisted of gas molecules super-saturated with ether, and free ether between the molecules, the result of the chemical combination of the material of which the spirit consists with the oxygen from the air. The water molecules super-saturated with ether (steam) give out their ether to the cold beaker; they contract and form groups of water molecules, and the beaker becomes covered with dew; this lasts but a short time, as the glass molecules speedily become saturated with the ether and expand, and then throw out ether to resaturate the water molecules and they disappear. Immediately above the flame, the water entities in the beaker, molecule after molecule, begin

to absorb the ether which passes through the glass (§ 140) and they become thereby specifically lighter and ascend. This absorption of ether, the consequent increase of dimensions of each molecule with the result that the molecule becomes lighter, is called by the physicist, specific heat or the "capacity for Heat." Tyndall makes this observation :—

"It is a noteworthy fact, that as the specific heat "increases, the *atomic weight* diminishes, and *vice versa;* "so that the *product* of the atomic weight and specific "heat is, in almost all cases, a sensibly constant quantity."* It is to be remarked here that the capacity for ether is not a constant, but always differs according to temperature and pressure, and when we heat a body the reaction goes on faster and faster. Physicists not recognising this fact endeavour to find the specific Heat of a material as if it were a "constant," and they fail; all manner of contrary results are obtained, and they are astonished at the failure. *See* Dr. Tyndall's work: "Heat, a Mode of Motion." Well may Dr. Tyndall observe, "These and "other discrepancies require explanation." †

169. As each molecule rises, charged with the fluid—ether, there comes in a struggle for the other molecules to obtain the excess of ether held by the rising molecule, for there is a tendency to distribute the ether fairly amongst the whole mass of water. But the spirit lamp

* "Heat: a Mode of Motion" (9th edition), 1892, p. 185.
† *Idem*, p. 265.

is still giving off this free ether, and the lowest molecules in the beaker are getting again a fresh supply. This produces a circulation in the water, the saw-dust becomes buoyed up by this circulation, just as our motes were buoyed up by the gaseous molecules (§ 121), and the saw-dust shows us the process going on in the water molecules. The water molecules, therefore, rise in the centre of the bottom of the beaker, carrying up the saw-

Fig. 65.

dust, and by the time they have nearly reached the top of the water they have lost to the surrounding molecules a considerable quantity of ether, and fall by the sides of the vessel to replace the molecules which are still rising. If the experiment is nicely done the reaction looks like a fountain in the water (Fig. 65). But the water is charged with air molecules. How do they get in? When rain drops it drops with force—it splashes the waters of the rivers, the lakes, the seas, and the oceans; thus the molecules

are all in a condition of very active motion. But the gaseous molecules of the air which press on the moving water are very much larger than the water molecules. What takes place when these small water molecules become charged with air molecules? Why, the larger air molecules get between the small and heavier water molecules, and because of the much greater gravitating power or weight of the latter they reduce the gaseous molecules to a like dimension to the water molecules; at the same time the air molecules, by contracting, give out ether to the water molecules, and the latter are warmed. Thus we have the gaseous molecule tending to expand and separate the water molecules, but the superior gravitating power of the water molecules actually compressing the gaseous molecule. The gaseous molecule becomes by this process converted into the liquid condition. Dr. Tyndall fully recognizes this fact, but does not grasp the operation. He describes the condition of things thus:—

"Gases are soluble in water—some more, some less. "Oxygen and nitrogen are thus soluble, and the same is "true of the atmospheric air formed by their mixture. "This dissolved air is a powerful enemy to the cohesion of "water; and when it is removed, the embrace of the liquid "molecules is greatly strengthened. Nature had in this "way liquefied these permanent gases ages before they "were liquefied by man." *

* "Heat: a Mode of Motion" (9th edition), 1892, p. 155.

The result of these gaseous molecules or, as we call them, vesicles of ether being mixed with the water molecules and the consequent absorption of ether by the water molecules or any object immersed in the water during the time the process is going on, as a thermometer may be, is thus described by the late Dr. Tyndall. He did not see the cause, but he clearly saw the effect. He considered that it is motion of the molecule, and that motion only, which he called Heat. A striking illustration that this is not so is described in § 196. Yet he could not see that it is not the motion of the molecule *alone*, but the motion of the liquid molecules absorbing *the gases of the air*, which produces the reaction called Heat!

"There are friends before me who have stood amid the "foam of Niagara, and I have done so myself. Had we "dipped sufficiently sensitive thermometers into the water "at the top and at the bottom of the cataract, we should "have found the latter warmer than the former. The "sailor's tradition, also, is theoretically correct; the sea is "rendered warmer by a storm, the mechanical dash of its "billows being ultimately converted into heat." He continues, in a foot-note: "I say 'theoretically correct,' be-"cause it would require far more care and instrumental "delicacy than appear to have been invoked, to prove that "the observed differences of temperature between sea and "air were due solely* to mechanical action. Nevertheless, "the tradition is an old one, as the following quotation "proves: 'In one of those gales on September 12th, Dr.

* Here Tyndall even gives expression to a doubt!

"'Irving tried the temperature of the sea in that state of
"'agitation, and found it considerably warmer than that of
"'of the atmosphere.'" *

The problem suggested here by Dr. Tyndall is solved in § 196, § 197; our instruments are equal to the experiments.

170. Let us proceed with our experiment: we now understand how air gets between the water molecules. Immediately after the convection currents set in, the compressed gaseous molecules, or gases in the liquid condition, having a greater affinity for the free ether given off the lamp than the water, absorb it, swell, collect together in groups at the bottom of the beaker, and they assume the form of air bubbles. The liquid air molecules are now true gaseous molecules, they quickly overcome the pressure of the liquid and the air above, and rise to the top and get to their native surroundings, the atmosphere. We must, however, carefully remark the following: at first when the water molecules are in slow motion these bubbles rise through the water nearly perfectly straight, but when the water molecules get warm and consequently larger, then there is a greater individual volume to resist in this ascending of the air bubbles. The larger the bubble the quicker it ascends; the larger the molecules the greater the resistance; now notice the result. The larger bubbles travelling

* "Heat: A Mode of Motion" (9th edition), 1892, p. 7. Dr. Tyndall, unfortunately, omits the year of this observation.

upwards faster than the smaller ones get a greater resistance and they no longer go up straight to the top, but with a wavy motion. Fig. 66 shows this reaction. As the temperature of the water molecules increases, their dimensions increase, the volume of the mass becomes greater, and this increase goes on faster and faster. It must be carefully observed whenever an air bubble starts from the glass to ascend, it is always an air bubble, it never disappears until

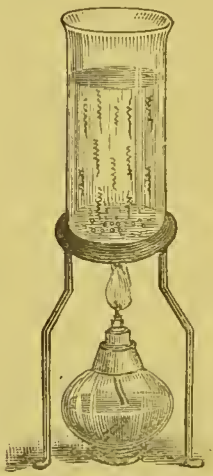

Fig. 66.

it rises from the surface of the water. When the air bubbles have disappeared, the convection currents become so fast as to assist in the production of what we believe to be an hitherto unobserved phenomenon. The current of free ether is assisted by this intense motion of the molecules, and the free ether rises through the glass in the form of so many cones—these consist of the same "optically empty" material—the free ether we have seen coming off the heated rod (§ 91), and we must notice also, this free ether comes

off generally from selected parts of the glass, some little excrescences arising from some foreign substances in the glass (which are better conductors of ether than the glass). These are points of conductivity, and from these foreign particles arise these cones of free ether. Fig. 67 shews the reaction. This is the first indication of boiling.

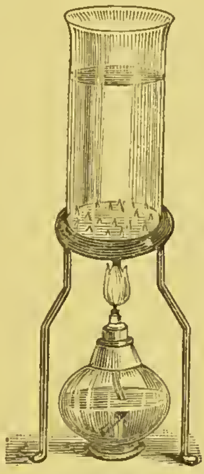

Fig. 67.

Now let us rest at this stage, and see what the books say :—

171. "When water boils in a glass beaker, the steam "is seen rising in bubbles from the bottom to the top, "where it often floats for a time, inclosed above by a "dome-shaped film." *

"If we observe the gradual progress of the phenomena "—as we can easily do in a glass vessel containing water, "we shall perceive that, after a time, very minute bubbles "are given off; these are bubbles of dissolved air. Soon "after, at the bottom of the vessel, and at those parts of the

* "Heat: A Mode of Motion" (9th edition), 1892, p. 158.

"sides which are most immediately exposed to the action "of the fire,* larger bubbles of vapour are formed, which "decrease in volume as they ascend and disappear before "reaching the surface. This stage is accompanied by a "peculiar sound, indicative of approaching ebullition, and "the liquid is said to be *singing*. The sound is probably "caused by the collapsing of the bubbles as they are "condensed by the colder water through which they pass. "Finally, the bubbles increase in number, growing larger "as they ascend, until they burst at the surface, which is "thus kept in a state of agitation; and the liquid boils." †

172. It may be here observed the singing noise mostly continues while the cones exist, and the sound is like a series of electrical discharges in very quick succession.

In text books the intermediate stages from convection to ebullition are generally badly described. The mode in which the air bubbles ascend is omitted, the existence of these cones of free ether is overlooked. To call these cones "bubbles" is a mistake—they are not bubbles; a bubble always appears as a spheroidal object, and never disappears in the hot water when once formed. These cones have no such appearance or reaction.

173. Presently, this free ether comes through the glass so rapidly that the water molecules cannot lick it up, or

* Here, it should be noticed, it is not at all necessary for the reaction to take place by "the action of fire." In a beaker placed above the Argand chimney (Fig. 64) the water would boil just as well as by the flame of a spirit lamp.

† "Elementary Treatise on Natural Philosophy," Part II., Heat, by A. P. Deschanel, edited by Prof. Everett (11th edition), 1889, p. 355.

absorb it fast enough, and thus for a certain distance there rises through the mass a quantity of free ether, and as it ascends it is absorbed and continued upwards as a mass of steam ; this is ebullition.

If Deschanel's statements were correct, viz. : the "large bubbles of vapour . . . decrease in volume as "they ascend and disappear before reaching the surface," then how comes it that the reaction is inverse to that

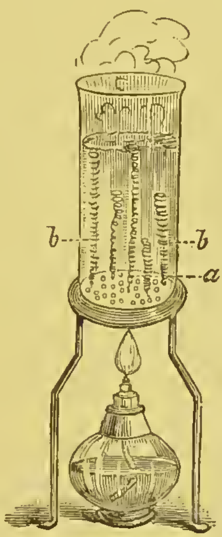

Fig. 68.

described by him ? If his observation were right, the steam coming from the bottom should be like a rough cone whose apex is *the top*. But the fact is the free ether coming through the glass *a* (Fig. 68) is less in dimensions than the molecules of water *b* super-saturated with ether now steam molecules, or water molecules in a vaporous condition, and we have thus a rough cone

whose apex is at the bottom. These molecules are in an intense state of agitation. Here is a true motion of impact and recoil like the mutual collision of billiard balls, or the reaction may be thus described:

Free ether passes through the glass resulting from the chemical reaction from the spirit lamp. As the ether rises between the water molecules, by its antigravitating power, it parts the molecules of water making an irregular tube. This is shewn at *a*; at a certain point *b* the water molecules have been able to absorb this fluid and become vaporous; we call this condition steam—here we have free steam in the water. Thus the ether being absorbed at about the position *b* by the water molecules, and thereby being converted into steam, they become vesicles of ether, or otherwise expressed, molecules of water gas super-saturated by ether, having a motion of molecule to molecule of an intense character of impact and recoil. This reaction is called ebullition. This is a view the physicist has not yet reached, as he has in like manner overlooked the conical forms of the free ether which he calls "bubbles."

174. Long before ebullition commences, the free surface of the water or the molecules which form the top layer of the water, spring up from the surface as gaseous molecules of larger dimensions than the surrounding cooler air molecules, and when in this condition we call these molecules steam.

As these steam molecules ascend they tear away by their buoying-up power some of the water molecules which have not expanded; this is quite a mechanical process, and when steam is in that condition it is called by the engineer "wet steam"; but if all the molecules are expanded it is called "dry steam." Steam consists of water molecules, all of which are in the gaseous form super-saturated with ether. The molecules give out a portion of this ether to the colder air molecules, and the ether then radiates through the air. When this reaction is finished, the water molecule exists in the air as a *gaseous* object of the dimensions, or, as it is called, the temperature, of the surrounding air molecules. Of course, this condition of things ceases when too many water molecules in the gaseous form exist among the air molecules—the pressure becomes excessive; the water gas molecules then become attracted to each other; they form groups of water molecules in the liquid condition, and fall as rain. Pressure, radiation of ether, temperature, and an undue number of water molecules are the factors in rain. The reactions are very complex and various.

175. How do we know all we have described? Because the eye can see this reaction! If steam is seen in a beam of strong light slowly ascending from the water it is not seen to be a continuous fluid, but a cloud like white dust. Those who have good eyesight can see the molecules of water gas coming out of their mouth if they breathe in a beam of sunlight when the beam exists in cold frosty air.

There is no illusion here. But by far the best way to see this interesting object—the water molecule—when it is super-saturated with ether, is by means of the microscope, thus: Take a small flask *a*, with a long neck, in which there is a little water in a state of *very slow* ebullition. It is found best to effect this, to cover the lighted spirit lamp (which should give a very small flame) with a glass receiver *b* open top and bottom, the whole

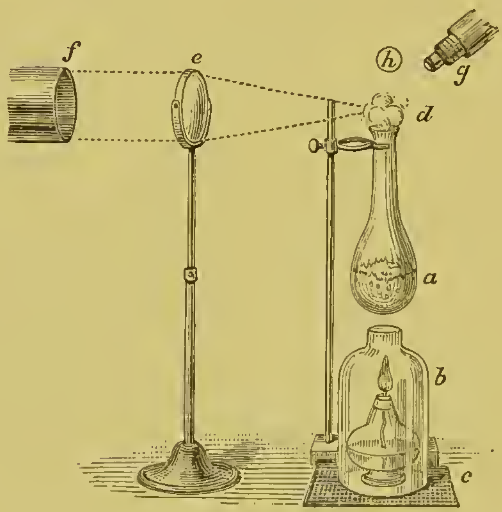

Fig. 69.

standing on very coarse wire gauze *c*. This allows a gentle air current to pass up between the receiver and the lamp. The free ether then slowly rises from the flame, attacks the bottom of the flask, and causes the evolution of steam in a very even and slow manner. To do this is the important part of the experiment, as otherwise the molecules of steam move so fast they cannot be observed; *d* is the steam issuing from the flask, and note

Fig. 70.

the fewer the molecules are the better they are seen. It is very strongly illuminated by the oxy-hydrogen lantern *c*, the rays of light being condensed as much as possible at *d* by the lens *c*; *g* is the object glass of the microscope. Because of the quick motion of the molecules a 4-inch power is best, but a 3-inch will do. This a difficult experiment, for everything depends upon the illumination. The light must be parallel to the mouth of the flask, and the object should be observed at right angles to the rays of light, so that the true position of the object glass would be at *h*. It is impossible in the engraving to draw the object glass in this position.

176. What is seen? The steam ceases to appear like a homogeneous substance, but appears as illuminated spheres like so many minute golden balls rising upwards. (Of course in the microscope this is inversed). *Notice the tiny globes are all of the same dimensions.* They come up in quick motion, sometimes moving one way, then another, often whirling round and round. Fig. 70 is a poor illustration of these beautiful, important and interesting objects, as seen by a common hand magnifying glass.

Now besides these spheres, there are seen here and there objects of a different class, they also look like spheres or spheroidal bodies, they are larger and brighter, they are not equal in dimensions, their motion is not the same as the water molecules; these are groups of water molecules which have not been expanded into vaporous molecules, but are buoyed up mechanically into the air and

there they evaporate into the gaseous form. These groups of water molecules constitute the "wet steam" of the engineer.

177. So we have here two reactions: the water molecule super-saturated with ether (steam), which contracts when it gets into the cold air until it becomes to the dimensions, or, as it is called, the temperature of the air; it then disappears to our sense of sight. This makes Avogadro's law approximately correct. Everyone has noticed that the steam from our engines takes longer to disappear in cold weather than in hot weather. Why is this? Because there is greater difference in dimensions to be overcome, hence it takes longer time to do the work of contracting than it does in summer. For the same reasons the steam from our breath is visible in winter and invisible in summer.

The second reaction is: the groups of molecules which have been mechanically raised and have not been expanded to the gaseous condition by absorbing ether become so expanded as they rise in the air, and in doing this they rob the air of the latent ether, and thus disappear from our sense of sight. This latter reaction can be seen (§ 186).

178. Now in this experiment the gaseous water molecules super-saturated with ether (steam) are only visible *

* Probably there is another way of seeing the molecule, namely: Professor Dewar has succeeded in making the gases of which the air consists luminous. The following (Fig. 70a) is the apparatus used by him, and his description of the experiment:—"Common air is first "dried and purified by passing through one vessel containing calcium "chloride, and another containing caustic potash; the latter absorbs "the carbonic acid. The air is next filtered by passing through a U

when they are mixed with the colder air, that is to say, when there is a great difference of dimensions; they are,

" tube filled with cotton wool, after which it enters through a carefully-" adjusted small tap, the two-bulbed vacuum tube represented in " the cut. . . . It makes no difference whether platinum, char-

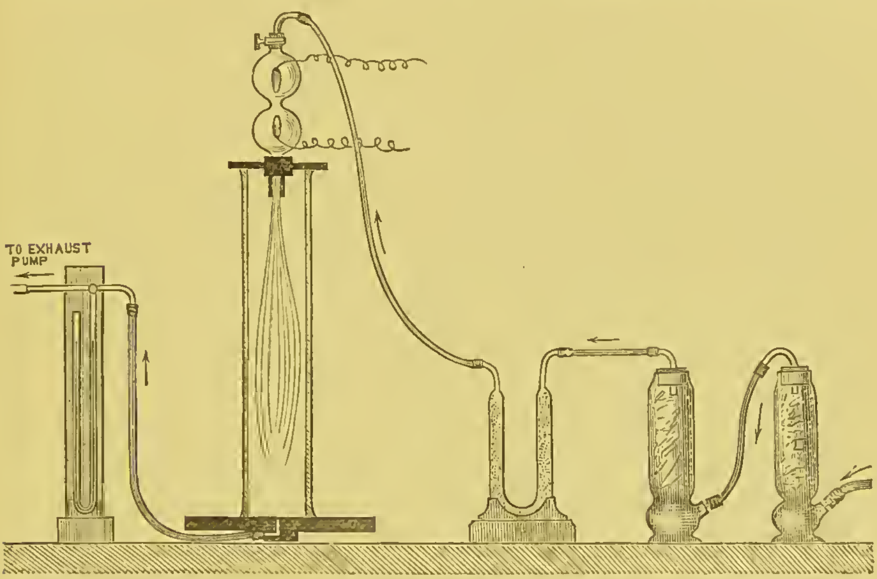

Fig. 70a.

" coal, or aluminium poles be used inside the vacuum tube. The lower " part of the tube opens into a tall glass vessel, connected below with " the exhaust pump and a mercurial pressure gauge. When the " current of highly attenuated air blows downwards through the " vacuum tube (which is surrounded by a box to prevent any light " being seen from the electrical discharge), a luminous glow, about " two feet in length, resembling to the eye the tail of a comet, appears " in the large vessel below." Obviously this illuminated matter consists of gaseous molecules, which are luminous *per se*, and it is highly probable if these molecules are examined by means of the microscope they will be resolved, and each molecule seen; and the appearance will be very similar to steam when examined by the microscope. The experiment is well worth trying, and the author would have made it if the apparatus were at his command. This experiment is described in the " Proceedings of the Royal Institution of Great Britain," June 8th, 1888.

therefore, not visible in the long tube of the flask. In like manner, when steam enters into hot air it is invisible, because the dimensions or temperature of the air entities are about the same as the gaseous water molecules. Whenever the super-saturated condition of atoms and molecules exists they are in a condition of vapour, and this is the difference between the vapour and the gas—it will be seen the difference is that of temperature. An important concept quite beyond the reach of the present ideas of the physicist.

179. There is yet another reaction resulting from the condition of things as explained. When steam is under pressure, it is like other gases—transparent (§ 159), but, acting under the energy imparted to the molecules by the rapid flow of ether through them, directly they flow into the air they increase in dimensions, absorb ether, and therefore feel cold. How is this? Because when they first get into the air they are in a condition of expanding—they are absorbing ether, and objects presented to the steam lose the ether and feel cold. The hand presented to such a strong jet of steam feels the steam as slightly cold steam. Hot air passing through a grating even has the same effect. The pressure from behind acting on the resistance of the grating causes the gas atoms and molecules to contract for a short time; they speedily recover themselves, but during that time they feel cold to the hand.

For exactly the same reason does the compressed air impinging upon the thermopile, as in our early experiments, show the reactions therein explained (*see* Part VI., § 63).

Thus are the concepts we have received in strict harmony with the phenomena in nature, and where mental chaos existed now mental order begins to reign.

X.

180. The next series of reactions we shall consider will be the crystallization of the liquid molecule. During the process of reduction of the gaseous condition to the liquid condition, we have a considerable contraction with the evolution of a considerable amount of free ether which radiates from the molecule, but during the time the liquid is becoming solid there is a much smaller contraction, very much less evolution of free ether, and consequently a much smaller amount of radiation.

We must refer back to our model (Fig. 27, § 111, § 112); call the shape and size of the model a molecule in the crystal condition; it is approximately angular, not the sharp and well-defined angles which exist in nature, but sufficiently defined to illustrate what takes place in Nature. We raise the temperature of this angular object by the absorption of air, being our hypothetical fluid—ether—in the model (Fig. 22, § 107), and the angular object assumes the spheroidal condition, it has absorbed ether, it has increased in volume, it is no longer angular, but it is a sphere—it is now in the fluid

condition; inverse the process, the ether is expelled by the sphere, the sphere ceases to exist, and the object is angular, so molecule adheres to molecule, the fluid condition ceases, and the mass of molecules becomes the

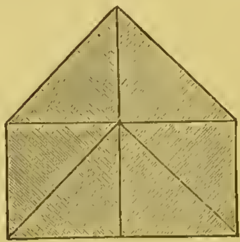

Fig. 71.

crystallized solid. If these crystals were to pack themselves into their closest conditions, thus (Fig. 71), where each triangular section represents a section of a crystalline molecule, then the law would hold good, that the volume of the mass would follow the loss of temperature, but if the molecules in the crystalline form do not pack

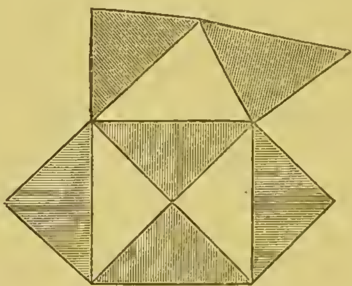

Fig. 72.

themselves in this closest manner (and we have seen that in Nature the liquid and gaseous spheres—molecules never exist in their minimum volume), but pack themselves in an irregular manner, illustrated thus (Fig. 72)

—like the crystals of loaf sugar or the crystals of snow, then we shall have a condition that the mass of crystals will be slightly larger than the minimum mass of the spheres—the liquid condition. Between the crystals would be either spaces filled with gaseous molecules or the spaces would be vacuous, hence the mass would become specifically lighter, so that if we float the mass in its own fluid it rises to the top as in the case of ice.*

These phenomena are so beautifully explained by Dr. Tyndall that we prefer to use his words, only altering so much, as according to our deductions, appears erroneous. We shall put such alterations in italics so that the difference can be readily seen, and thus the reader can refer to his work and compare the difference of concept. Now,

* "Ice on liquefying *contracts*; in the arrangement of its molecules "to form a solid, more room is required than they need in the neighbour- "ing liquid state. No doubt this is due to crystalline arrangement. "When the crystallising force comes into play, the attracting poles of "the molecules unite so as to leave larger interatomic spaces in the "mass. We may, as already explained, suppose the molecules to attach "themselves by their corners, and, in turning corner to corner, to "cause a virtual augmentation of bulk. At all events, the molecules "retreat from each other when solidification sets in. It is evident "that pressure, in this case, would resist the expansion which is "necessary to solidification, and hence the tendency of pressure, in "the case of water, is to keep it liquid. Thus reasoning, we should be "led to the conclusion that the fusing points of substances which "expand by solidifying are *lowered* by pressure."—"Heat: A Mode of "Motion" (9th edition), 1892, p. 148.

In conveying this concept, which absolutely follows the fact, it is very interesting to observe how the mind of the physicist, confined by his mathematical reasoning, struggles to get from the erroneous to

if the reader will take Dr. Tyndall's work and make similar alterations throughout his book, he will be surprised to see what harmony and clearness runs throughout his valuable work.

His instruments for testing the reactions are the same as ours, the thermopile and the galvanometer.

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truth. Thus Dr. Tyndall endeavours to convey the concept, and illustrates the view thus (Fig. 73):

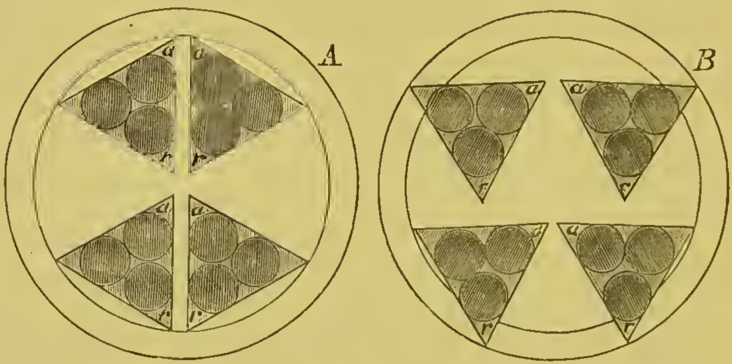

Fig. 73.

From Dr. Tyndall's "Heat: A Mode of Motion" (9th edition), 1892, p. 108.

He represents Fig. *A* as a group of four water molecules, consisting of three spherical objects—two of hydrogen, one of oxygen; this is water in a liquid condition. Then he re-arranges the groups, so that they may become crystals, whose poles or corners, as in *B*, touch each other, and the four groups thereby become increased in volume, thus accounting for the increase in volume from 39° Fahr. to 32° Fahr. To convey this idea, he is obliged to surround the *spherical* atoms or molecules with a material to assume the crystal form, while he *absolutely denies the existence of such a factor in the process.* It is here, especially, the human mind fails when it adheres strictly to the kinetic theory.

" I place a lens in front of the ice, and cast a magnified image of the " slab upon the screen. Observe that image." . . . " Here we have " a star, and there a star; and as the action continues, the ice appears

181. He says: "I take the thermo-electric pile with "its back upon the table, and on its naked face a thin "silver basin" (Fig. 74 *a*), "which contains a quantity of

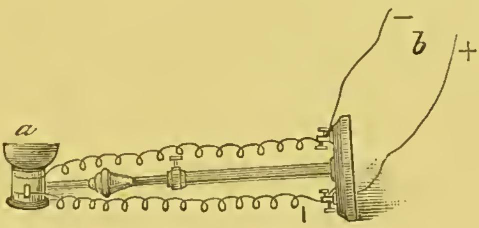

Fig. 74.

"water slightly warmed. The needle of the galvanometer "swings to 90°, and remains permanently deflected at 70°. "I now drop a little powdered nitre, not more than will

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" to resolve itself into stars, each one possessing six rays, each one " resembling a beautiful flower of six petals. When the lens is shifted " to and fro, new stars are brought into view; and as the action con- " tinues, the edges of the petals become serrated, and spread them- " selves out like fern-leaves upon the screen. . . . There are two " points connected with this experiment, of great minuteness, but of " great interest. You see these flowers by transmitted light—by the " light, that is, which has passed through both the flowers and the " ice; and you see a bubble in the centre of each flower. In many " cases the bubble moves before your eyes. When you examine the " flowers by allowing a beam to be reflected from them to your eye, " you find in the centre of each flower a spot shining with the lustre of " burnished silver. You might be disposed to think this spot a bubble " of air; but you can, by immersing it in hot water, melt away the " circumjacent ice. The moment the spot is thus laid bare it collapses, " and no trace of a bubble is to be seen. *The spot is a vacuum.* We " know that ice in melting contracts; hence the water of these flowers " cannot quite fill the space of the ice by the fusion of which they are " produced; a vacuum necessarily accompanies the formation of every " liquid flower."—*Idem*, p. 154. The words, coupled with the illustration, "The attracting poles of the molecules unite so as to leave larger " interatomic spaces in the mass," are unthinkable when they are applied to spheres.

"cover a threepenny-piece, into the basin, and allow it to "dissolve. The nitre was previously placed before the fire, "so that not only was the liquid warm, but also the solid "powder. The effect of their mixture is this. The nitre "dissolves in the water; and to produce this change," *the crystal molecules of nitre absorbed ether, and caused a current of ether to flow from the thermopile.* "The needle not only "sinks to zero but moves strongly up at the other side, "showing that the face of the pile is now powerfully "chilled."

All this chilling was the result of the crystal molecules swelling from the angular to the spheroidal by the absorption of ether in order to obtain a change of form as explained by our model (§ 107).

"Pouring out the chilled liquid, and replacing it by "tepid water, the permanent deflection of 70° is repro-"duced. I introduce a piece of common salt. The "needle sinks, reaches zero, and moves up on the side "which indicates cold. But the action is not at all so "strong as in the case of saltpetre." . . . "Putting "a little sugar, instead of salt, into the warm water, the "chilling is sensible, but is much less than in either of the "former cases. Thus, when you sweeten your hot tea, "you cool it in the most philosophical manner; when "you put salt in your soup, you do the same; and if you "were concerned with the art of cooling alone, and careless "of the flavour of your soup, you might hasten its refrigera-"tion by adding to it saltpetre. In our fourth Lecture a "mixture of pounded ice and salt was employed to obtain "intense cold. Both the salt and the ice, when they are "thus mixed together, change their state" *by the molecules*

altering from the angular to the spherical, and this shows the rapid absorption or "soaking in" of ether, in order to convert the crystal molecule into the liquid sphere. "As a consequence "the temperature of the mixture sinks many degrees below "the freezing point of water. By this cold we are able to "burst our iron bombs," *because during the time the spheroidal molecules of water were giving out ether, and forming the crystals which did not pack themselves so closely as when in the liquid condition, they occupied a larger volume, and with such a force as to break the iron bombs.*

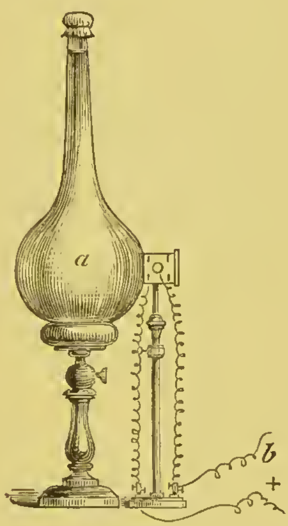

Fig. 75.

"I will now reverse this process, and endeavour to show "you the heat developed, in passing from the liquid to "the solid state. But first let me prove that when sulphate "of soda is dissolved" *ether* is absorbed. "Testing the sub-"stance as the nitre was tested, as the crystals of the sul-"phate melt the pile is chilled. The complementary experi-"ment is here arranged. A large glass vessel" (Fig. 75 *a*), "with a long neck, is filled with a solution of sulphate of

"soda. Yesterday the substance was dissolved in a pan "over our laboratory fire, and this bottle was filled with the "solution. The top being carefully covered with a piece "of bladder, the bottle was placed behind this table, where "it remained undisturbed throughout the night. The "liquid, at the present moment, is super-saturated with "sulphate of soda. When the water was hot, it melted more "than it could melt when cold; and now the temperature "has sunk lower than that which corresponds to the point "of saturation. This state of things is secured by keeping "the solution perfectly still, and permitting nothing to fall "into it. Water, kept thus still, may be cooled many "degrees below its freezing point. Some of you may "have noticed the water in your jugs, after a cold winter "night, partially freeze on being poured out in the morning. "In cold climates this is not uncommon. The molecules "of sulphate of soda, in this solution, are, as it were, on "the brink of a precipice, and may be pushed over it, by "simply dropping a small crystal of the substance, not "larger than a grain of sand, into the solution. I cut "away the bladder and drop the bit of crystal into the "clear liquid; it does not sink, the molecules having "closed round it to form a solid in which it is now "embedded. The passage of the atoms from a state of "freedom to a state of bondage goes on quite gradually; "you see the solidification extending down the neck of the "bottle. The naked face of the thermo-electric pile rests "against the convex surface, and the needle of the galvan-"ometer points to zero. The process of crystallisation now "approaches the liquid in front of the pile. This solidifies "and develops" *ether*, "which, communicated to the glass "envelope, warms the pile, and the needle flies to 90°. "The quantity of" *ether* "thus rendered sensible by solidi-"fication is exactly equal to that which was rendered latent

"by liquefaction. The latent" *ether* "of liquids is thus "illustrated." *

We might continue illustration after illustration, all conveying the same harmonious idea, but it is not our object to write a full text-book or great treatise on this subject. The illustrations given apply to all matter capable of crystallisation, but in different degrees according to the specific species of matter. The law may be thus stated: Give the atom or molecule a sufficient quantity of ether, and a sufficient internal pressure (strain) and certain specific latent activities become potential, or, as the physicists state the case, kinetic energy is evolved. Thus we come to understand that the so-called kinetic energy is molecular motion—the molecule does work. The concept is simple. But it is not the motion described by the physicist.

XI.

182. Before we proceed further, it may be as well to say something of the radiation of ether. In our model (Figs. 25 and 26, §§ 110 and 113), we obtained the idea that when the inflow of ether *through the atom or molecule* exactly was equal to the outflow, we had the simple reaction called "radiation." When the inflow of ether exceeds the out-

* "Heat: A Mode of Motion" (9th edition), 1892, p. 194.

flow, it is radiation and increase of temperature (*i.e.*, the increase of the volume of the entity or unit).* When the outflow of ether exceeds the inflow, we have radiation and a decrease of temperature (*i.e.*, the decrease of the volume of the entity or unit). The concept is clear and complete. Having seen ether (§ 91), having seen the molecule (§ 176), and having seen the vibration of the molecule (§ 125), we *feel* we know at last what we are talking or writing about. We have now definite ideas. The difference, therefore, between solids and liquids, vapours and gases, is only this: in the first, atoms or molecules adhere or cohere to each other; in the last three, the atoms or molecules are free, *i.e.*, have locomotion—they only attract each other. The latter, however, are in contact, except when they are separated by considerable vibration, giving a reaction somewhat like the mutual impact and recoil of billiard balls (§ 115 and § 155). Little need be said about solids, because the whole which has been said of liquids and gases applies to the solid, except there is no relative displacements of the atoms or molecules, or both, of which the solid is built up.† The reader will now readily understand the models shown in Figs. 23, 24, 26. Every species of atom or molecule has its specific conductivity and specific tem-

* *See* § 7, for definition of the unit.

† This statement wants qualification, because in some solids, especially of organic formation, a *very slow* molecular alteration often takes place, generally attended by an evolution of ether (Heat) showing that chemical reaction is taking place.

perature under a definite internal pressure or intensity of flow of ether. Of course, between the solid and liquid there are degrees of solidity, giving the plastic and viscous.

We must ever keep in view the concept that the fluid ether is always present, and is always in motion (§§ 185, 195). If, therefore, ether is flowing very slowly and not effecting the dimensions of the atom or molecule, we call this motion or current of ether "radiation." When the internal pressure of ether is greater, or when it is less, thus altering the volume of the object, we say the mass alters in temperature. If radiation through the molecule be excessive, then we have incandescence. How simple is the idea! In a progressive mental development, men seem to struggle to hold to the complex! In the order of things this seems to be right, but it is difficult to understand why it should be so.

Now, with the concept here given, if the reader will take Dr. Tyndall's "Heat: a Mode of Motion," and attentively read that part of the work on radiation,* he will find he possesses a harmonious view, explaining all the experiments. Notice particularly if the radiation of ether be brought to a focus by means of a lens, although the concentration is invisible in air devoid of motes, yet if we put certain objects in that focus, they become incandescent. Consider the fire syringe (§ 134): by pressure we cause the air molecules to contract and to give out their ether, which

* "Heat: A Mode of Motion" (9th edition), 1892. Lecture XV.

radiates through the metal of the syringe, and the ether is conducted freely away; but in the tinder we have the same radiation, and under its intensity the tinder becomes red-hot—incandescent. Also consider the reaction of lighting wood by the current of free ether from the chimney of an Argand burner (§ 167). In all these experiments the reactions are the same, namely: let ether pass through certain classes of molecules at a certain intensity, and then the molecule vibrates—it is incandescent.

XII.

183. We now proceed to give various illustrations, amplifying the concept received.

First, let us draw attention to the fact, a most important fact, *that the text-books and works on Heat* we have examined *are at a loss to explain the phenomena relating to distillation!* Thus, Clerk Maxwell, in his "Theory of Heat," does not mention it! Dr. Tyndall, in "Heat, a Mode of Motion," ignores it! Deschanel gives a page to a statement that such a process exists, and draws a picture of a still, but gives no real explanation of the operation! * So does Balfour Stewart,† whilst Garnett shows in a

* Deschanel's "Natural Philosophy," Part II., Heat (11th edition), 1889, pp. 368-9.

† "Elementary Treatise on Heat" (5th edition), 1888, p. 110.

few lines that distillation is due to the pressure of vapour.* None attempt to explain the all-important fact: *Why the molecule ascends in the receiver.*

Yet how simple and instructive the process is! Devoid of technical detail it may be explained thus: Mixed classes of molecules are placed in a vessel, which is heated from below. The result of the decomposition arising from the fuel gives free ether (§ 140), which passes through the receiver into the liquid molecules it contains. Each class of molecule seizes this ether, and the molecules being in a liquid condition, that is they are free to take independent locomotion by the process which the physicist calls convection currents, the molecules charged with ether become specifically lighter and rise through the mass. Otherwise expressed, those molecules which have the greatest affinity for ether and are most favourably placed will rise above the fluid first. New supplies of molecules thus super-saturated with ether, that is molecules in the vaporous condition, rising from the surface of the fluid, are pressing the upper ones upward and onward. They are thus moved on to the worm of the condenser. This being surrounded with cold water, the cold water molecules seize the ether from the molecules in the worm, and the latter then decrease in volume by the loss of ether, or as it is called become reduced in temperature, and thus the vaporous is converted into the liquid, molecule

* "Elementary Treatise on Heat" (5th edition), 1889, p. 117.

after molecule they roll down the worm of the condenser by gravitation. The class of molecular matter which has the greatest affinity for ether seizes it first, becomes vaporous, and comes away first. The art of distillation is being able to separate correctly the "first comers." That is all. The whole history of distillation is thus told! Mr. Kinetic Theorist, can you explain it? If so, why do you not do so?

184. One of the neatest illustrations of the reality of this fluid ether is to observe it buoy up a small spheroidal mass of water. Perhaps Deschanel shows the prettier picture, so we will copy it. The free ether coming through

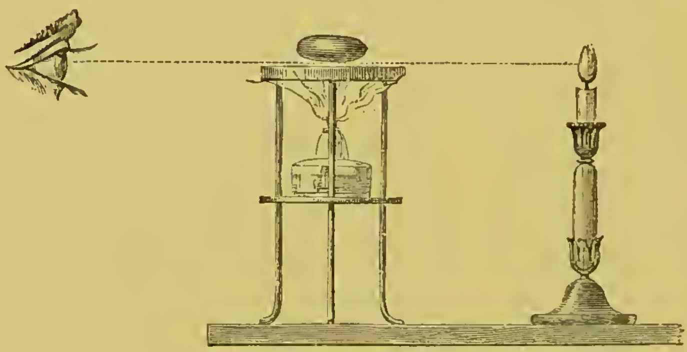

Fig. 76.

a heated plate buoys up the mass of fluid, and the light is easily seen between the plate and the spheroidal mass. How simple is the explanation! Yet Deschanel says:

"Various attempts have been made to account for the "absence of contact between the liquid and the metal, but "the true explanation is as yet uncertain." *

* "Natural Philosophy," Part II., Heat (11th edition), 1889, p. 367.

We must look at this experiment in the light of the other experiments. The fluid ether absolutely surrounds the spheroidal mass of fluid. Diagram Fig. 77 shows the operation in section, where the uprising ether is shown as

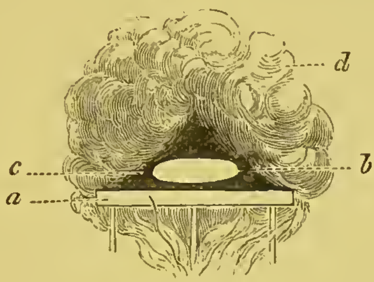

Fig 77.

b, the heated plate *a*, the spheroidal mass of fluid *c*, and the "optically empty" gases with intermolecular free ether *d*. Compare § 91, § 135, § 136, § 140.

Fig. 78.

Similarly text-books show the condition of water in a red-hot silver basin, and Fig. 78 shows the condition of the liquid.

The liquid is seen in plane, and the corrugated edges show where the free ether is "rippling" or flowing up from below and through the fluid.

185. In § 81, *20*, we stated:

"Ether is ever present. It, like atomic matter, cannot "be created or destroyed. It is always in motion. Its "small radiations are generally unrecognised. It flows in "currents and streams like any other fluid."

One only needs to consider a thermometer to know this is the case, for the molecules are always altering in temperature by the more or less "soaking in" of ether. But the thermopile and galvanometer tell much more than a thermometer can. Professor Garnett states:

"If we enter a very cold room, and touch various articles "in the room, we find the metal articles feel coldest of all, "and of these we notice that large masses of silver or "copper feel especially cold to the touch, while the wooden "furniture produces the sensation of cold in a less degree, "and the hearth-rug, or other woollen materials, hardly "seem cold. Now, if a thermometer be brought into con-"tact with all these articles in succession, it will register "the same temperature, the reason of the difference to the "touch being that the metallic bodies transmit heat through "their own masses, and so take it away from the hand, "much more readily than wood, and wooden articles much "more readily than woollen materials. In fact, the bodies "which feel colder than others, seem so, not because they "are at lower temperatures, but because they are better "conductors of heat." *

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* "An Elementary Treatise on Heat," by William Garnett, M.A., &c. (5th edition), 1889, p. 161.

Let us consider this statement very closely. We have seen (§ 141) that molecules super-saturated with ether, and probably free or inter-molecular ether, streams off the human body. It is the rapid seizing and conducting the ether by metals that causes them to give us the sensation of cold; but, to say as Garnett does, that when a thermometer is brought into contact with various objects it will register the same temperature, therefore the bodies which feel to the human being colder than others, are *not* colder, but are better conductors of Heat, is not exactly correct; and this is easy to prove by the thermopile. We will proceed to demonstrate this, but before doing so we will explain a series of experiments which lead up to this correction, and also review much we have demonstrated.

186. In § 177 we stated that we could see the groups of water molecules spring into the gaseous condition and disappear, and we also observed (§ 142) that under certain conditions we can see the water molecules super-saturated with ether, *i.e.*, as steam, coming out of the mouth. We now take a piece of silver or a piece of copper, silver-plated, say 3 inches long, $1\frac{1}{2}$ inches broad, and $\frac{1}{8}$ inch thick. The size is not material, the important points are: The upper surface shall be bright, and the lower quite flat, so that when placed on the thermopile each pair of metals shall touch the bottom of the plate. Take a glass tube, and through it blow by means of the mouth on the surface of the plate. The vapour from the mouth,

consisting of, in great part, water in the form of steam, that is molecules super-saturated with ether, which condense, as it is called, on the plate. The water molecules give out their ether to the plate and contract; they group themselves into small groups—drops of water, and thereby a thin layer of water is deposited on the surface of the plate. Such may be called a section of water. Let us repeat the experiment. Place the plate on the stage of the microscope and strongly illuminate it. Breathe on it as before. By means of the microscope we see the minute drops of water attracted to the metal. Now observe the reaction—the groups of water molecules dart upwards, and the instant they dart off the surface they disappear. The reaction is this: When the molecules reach the surface of the plate they are in a condition of super-saturation of ether, *i.e.*, steam; they speedily contract to the very minute sphere the liquid water molecule, giving out ether to the metal when they contract; but when they dart off the surface of the plate they expand and reabsorb ether; they do not, however, expand to a condition of super-saturation, but only to about the dimensions of the air molecules, they may then be called water in the gaseous form. What is the result? As they do not take so much ether from the plate as they gave to the plate, they leave the plate charged with ether—it is, as it is commonly termed, warm, after the reaction. The observation of this one experiment teaches us more of the process of evaporation than any mode of reasoning

possibly can, because we *see* the actual reaction. It should be here noticed, it is not so much the rapidity the molecules spring from the surface of the plate, which makes them disappear, as the rapid conversion of the liquid molecules into the gaseous condition.

187. Now to the proof of the statement. We put the plate on the thermopile. After a short time the needle of the galvanometer registers zero. When this is the case switch off the connection between the galvanometer and the thermopile; breathe on the plate as before, and carefully watch when the whole of the groups of water molecules have darted off the plate into the air. This is easily seen. Directly the reaction has taken place switch on the connection, and immediately the needle of the galvanometer records the reaction of Heat, showing that the plate has increased in temperature *after* the reaction.

188. We follow up the concept by the following interesting experiments. Here is a small copper bowl $2\frac{1}{2}$ inches high and 3 inches across. Its bottom is flat, accurately level, so that it touches all the junctions of the thermopile. It has a handle, made of silk, like the handle of a pail. Here also is a long glass rod by which we can move about the bowl, as illustrated (Fig. 79).

The object of the long glass rod is to prevent any influence from the hand or the body acting on the bowl. The experiments are so delicate that a momentary touch of

the hand on the copper bowl, or even the radiant Heat from the body, affects the experiment. By means of the rod we rest the bowl on the face of the thermopile (Fig. 79), and then allow the needle of the galvanometer to go to zero. Here is a glass bottle accurately stoppered and filled with water. It has been a considerable time by the side of the bowl, so that the water is at the temperature of the bowl. In the bottle is a thermometer, which registers the same temperature as another thermometer at the side

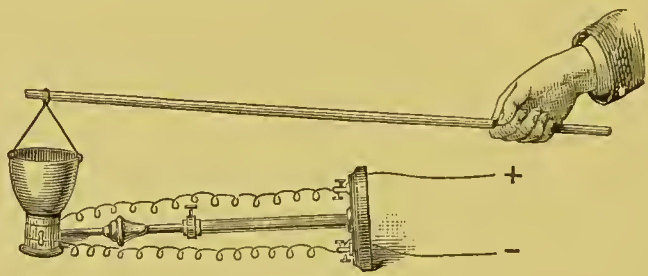

Fig. 79.

of the bottle, thus showing the internal and external temperature is the same. We carefully pour a little of the water into the bowl. There soon is a constant deflection of the needle in the direction of cold. This deflection remains nearly constant so long as any water remains in the bowl. The deflection slightly varies according to the temperature of the room.

189. What is taking place? On the surface of the water, the minute water spheres—molecules, being the top layer, spring up into the air as we saw from the metal plate (§ 186), they seize the ether from the mass of water, and to replace the deficit of ether a current of ether passes

through the bottom of the bowl from off the surface of the thermopile. This losing ether causes the reaction of cold, which is recorded by the needle of the galvanometer. The expansion of the molecule by absorbing ether may be compared to a "sucking-up" of ether—this is evaporation. It is a true "pull," not a push. How do we know this is the cause of the reaction? The reply is: insert a bung into the mouth of the bowl; evaporation ceases, and the needle goes to zero. Or better still, take a liquid which does not evaporate (or evaporates, as we shall see, so slowly that we obtain no reaction, § 191), and which is lighter than water—such a liquid we find in olive oil—pour a little on the surface of the water, evaporation is immediately arrested; the water molecules cannot spring from the surface through the lighter material protecting the upper surface of the mass of molecules, and the needle of the galvanometer goes back to zero.

190. But there is another still more important reaction to observe. When the molecule springs from the surface of the mass of molecules—the water, the instant it leaves the surface it is beyond the influence of the mass to get ether from it, and to thereby further increase in volume. In order to be about the dimension of the air molecule it must get more ether. Where does this come from? The answer is: From the radiation of ether through the air molecules; hence there is not only a flow or current

of ether from off the thermopile through the copper and through the water, but also towards the surface of the water. How can we prove this? Put the thermopile with its face resting just over the surface of the water; it gives up the ether instead of the air, and the needle of the galvanometer gives the reaction of cold. Another way to show this reaction is to place the thermopile about $\frac{1}{4}$-inch over the mouth of the bottle of water (§ 188), the bottle being nearly full. We get the reaction of cold, but not such a decided deflection as we obtain from the open bowl, because the molecules are freer to expand in the latter case. Now in these illustrations we have decided molecular motion, and this motion is called by the kinetic theorists Heat, § 47. The reaction as explained by the thermopile is: this motion is not Heat, but Cold!

191. We have said that the oil does not evaporate, or evaporates so slowly that no reaction can be obtained. This is easily proven by substituting oil for water in the bowl. The needle remains at zero all the time the oil is in the bowl.

192. In the next experiment we get an important verification of the statement made in § 154, namely: If the temperature remain low there is no vapour of mercury rising from the mass as we find in water. Put a quantity of mercury in the bowl while it is resting on the face of the thermopile. There is no deflection of the needle, showing there is no evaporation.

193. But the experiment of evaporation of water in the copper bowl shows a very remarkable property. As each molecule expands by absorbing ether, although the process is so slow and apparently so weak, yet it has the power of passing the current of ether through the best non-conductors of Heat and Electricity. Take a piece of ebonite, say $\frac{1}{8}$-inch thick, or a piece of glass, say $\frac{1}{4}$-inch thick, and place them on the face of the thermopile, either separately or together, and the bowl with water in it resting thereon, and there is only a very slight alteration in the deflection of the needle of the galvanometer in the direction of cold to what takes place if the bowl rested directly on the thermopile!

194. A very curious observation should be here noticed. In § 89 it was seen that when a stream of gas passed through gas at a low pressure, there was little resistance to the flow. So also it was seen, § 91, when free ether passed through gases very slowly and in a very small quantity, it passed through gases with less resistance, and tends to the demonstration of a law: the less the pressure, the less the resistance. May it not be, therefore, in the experiment of evaporation, the current of ether is so small and the flow so feeble that a non-conductor cannot offer resistance?

195. We now proceed to a series of experiments to show that the observation of Garnett (§ 185) is not correct—namely, that objects under like external condition are

at equal temperatures. Here is the bowl empty and quite dry, suspended from a glass rod only a quarter of an inch from the face of the thermopile. Between the bowl and the direct light is a screen, to screen as much as possible the direct radiation from the window.

We let it remain there, and from time to time, by means of the long glass rod (Fig. 79), carefully place it on the face of the thermopile. We obtain most extraordinary results—nearly always deflections to Heat—sometimes a large deflection, sometimes a small one, and rarely a deflection hardly appreciable, but *sometimes a deflection of cold.* Beside

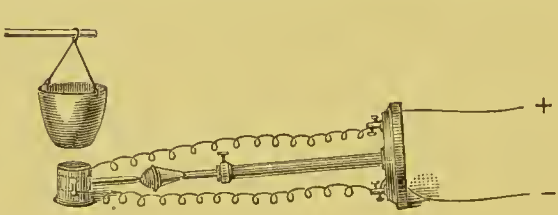

Fig. 80.

the thermopile is a white porcelain dish lying on the table; let the bowl rest some time on it, and then by means of the rod place it on the thermopile, and we obtain almost uniformly a deflection of cold. Lodge the bowl on any object near the thermopile, and apparently at the same temperature, and we obtain different deflections! If we allow a delicate thermometer to rest in the bowl in all these experiments, we have no alteration of the temperature as recorded by the thermometer. Thus we see conclusive evidence: that each class of matter has a distinct but generally different temperature, and that, if we are dealing

with a fluid, as we believe we have proved, this fluid is ever present. We are surrounded by, and we exist in, and absorb this fluid as similar objects do in the liquid of the ocean. How grand and important then is the concept: an incompressible fluid, invisible under ordinary conditions, ever present—a fluid which is the factor, by which the activities of atomic and molecular matter are evolved, and we call these activities energy, force, Life!

195A. We will now more fully consider the foregoing experiments, and to do so we will use a still more

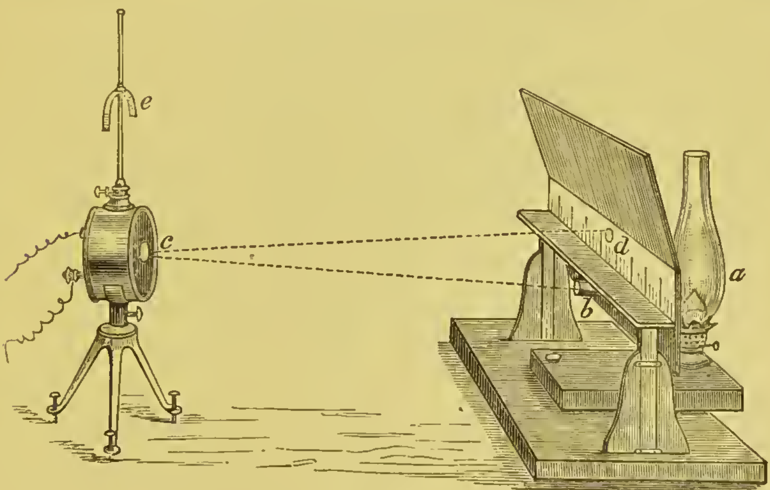

Fig. 80a.

sensitive apparatus than we have hitherto used; it is called a "mirror," or "reflecting galvanometer," illustrated in Fig. 80a.

In construction it is fundamentally the same as the instrument we have hitherto used (Fig. 6). We are going, by this instrument, to record most delicate results. Instead

of there being one pair of needles, as in Fig. 5, these instruments have four or more pairs of needles, each series pointing in contrary ways, as in Fig. 5. Thus, suppose the instrument have a series of four pairs, then the upper four will tend to point to the north, and the lower four tend to point to the south, or *vice versâ*. The needles are very short, and the wires are so wound round the needles as to give very sensitive results. The upper series of needles are fastened behind a small mirror *c*, and the lower are below the upper, as in Fig. 6. A lighted lamp *a* sends a beam of light through the small lens *b*; this beam of light is reflected from the mirror *c* to the scale, and thus there is a small illuminated disc or spot of light upon the scale *d*. The lens *b* has a vertical line on it, which is reflected upon the illuminated disc *d*. This line very accurately indicates the movement of the mirror. Above the galvanometer is a controlling magnet *e*. By this magnet the line on the disc *d* can be brought to 0 (zero), which is in the centre of the scale. Divisions are made upon the scale each way, from 0 to 350. When the instrument is connected with the thermopile it is extremely sensitive to differences of temperature. If the face of the thermopile is warmed in the very slightest degree the pointer goes one way, or if it is chilled in the very slightest degree it goes the other way; and as the mirror is 35 inches from the scale, an almost infinitesimal movement on the mirror shows a considerable deflection on the scale.

So delicate is this instrument that if it is connected with an ordinary pin and needle, and they are dipped in a drop of water made acid, in the very slightest degree, the illuminated disc goes right off the scale!

The second piece of apparatus is a wood box (Fig. 80b), through the upper part of which is passed a mercury thermometer *d*. There is a small hole in the box close to the thermometer, through which passes a silk thread *a*,

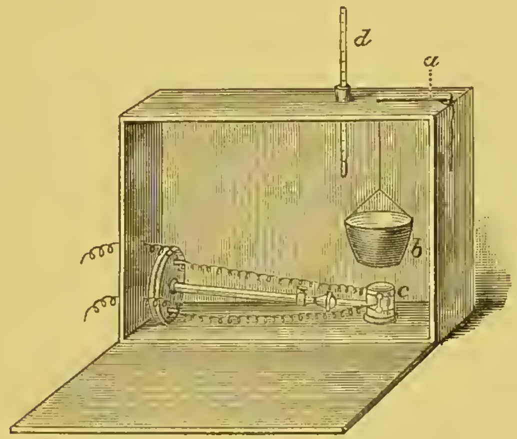

Fig. 80b.

which is fastened to a pin. This thread supports the copper bowl *b* (§ 188), and by it the bowl can be raised or lowered. The thermopile *c* is placed in the box with its face upwards, so that when the bowl is lowered it will fall exactly on the face of the thermopile. The latter is connected with the reflecting galvanometer through small holes in the side of the box. The lid being closed, no light can influence the experiments, and the radiation from the body is screened from the thermopile by the

box. The copper bowl can be raised or lowered to different heights, and it can be rested on the thermopile in a very delicate manner indeed. The thermometer registers the temperature of the inside of the box, and the readings can be taken outside. Beside this apparatus is a barometer, so that the readings of pressure can be readily recorded.

We repeat the experiments in § 188 to § 195, and in addition to the confirmation of the results obtained, we gather the following further evidence:—

a. Not only do we obtain contrary reactions of Heat and Cold from the empty copper bowl, but we find that the general results are: as the temperature rises, as recorded by the thermometer, the deflection increases, and as it falls the deflections become less. Obviously the rise and fall of the thermometer is a factor, but not one we can with certainty record. The differences in the atmospheric pressure as recorded by the barometer, are not appreciable—they are most likely too slow to have any effect.

b. With the ebonite or glass (§ 193) on the face of the thermopile, we have the same reactions as before, but the deflections are greater through the thick glass ($\frac{1}{4}$-inch thick) than through the thinner ebonite ($\frac{1}{8}$-inch thick). Both these, however, reduce the deflection.

c. If we put oil in the bowl, we obtain deflections in the directions generally of Heat, sometimes of cold; these deflections appear to be from the copper bowl, and not from any evaporation from the oil.

d. With water and oil on the top of the water, the deflections are generally in the direction of Heat, again showing the copper bowl is the source of radiation.

e. With water in the bowl there is always a deflection to cold.

f. Generally we find that when the bowl is suspended about 1½-inch from the thermopile, it effects the instrument, and as it is lowered closer to the thermopile the effect is increased until contact takes place, and then the deflection is very marked.

In all these results obviously the copper bowl is an important factor in causing radiation, although every effort has been made to prevent any alteration in temperature to the external air.

We substitute a very thin silver basin which is very shallow, and fill it ½-inch with absolute alcohol. Now we obtain much more reliable results (indeed, generally, with the thin silver bowl the results are reliable as compared to the copper bowl).

g. The deflection is always in the direction of cold, and there is a very marked difference when the bowl

is close to the thermopile, that is $\frac{1}{8}$-inch from the instrument in the direction of cold to what exists when it is $1\frac{1}{2}$-inches away, and when contact takes place between the bowl and thermopile the deflection to cold is very considerable, nearly always the spot of light goes very far off the scale.

h. The lighting of the gas or a gas fire effects the experiments in the direction of Heat.

i. The opening the lid of the box, and thus letting in the light, does not very materially effect the experiments.

j. If we put the thermopile $\frac{1}{2}$-inch over absolute alcohol in the silver bowl, we obtain a very marked deflection of cold, and this deflection exceeds the deflection from water placed under like conditions.

All these experiments with this delicate instrument confirm our previous experiments and the deductions from them. Ether is ever present, and the absorption of ether by the molecule always causes radiation of ether to the absorbing molecule; and this radiation of ether always produces the reaction of cold, even to effect the thermopile two inches from the expanding molecules, so that the stream of ether, passing through the air, from the thermopile to the bottom of the bowl is quite marked.

196. We will next consider the following: Take a piece of glass tubing about 4 inches long, $\frac{3}{4}$ inch external

diameter, and into it insert a piece of cork, and sink the shank of a flat-faced brass button into the cork. We have thus the button with a glass handle. The holding the button by means of this handle prevents the heat of the hand having any material influence on the button. We have covered the top with sealing wax, and put some sealing wax round the upper part of the button; this gives a finish to the apparatus, and makes the button firmer in the cork. The following shows the instrument (Fig. 81) :—

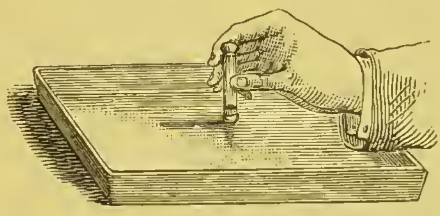

Fig. 81.

We take an ordinary porcelain dish—a developing dish, as used by photographers, 10 inches by 8 inches, answers very well. The button rests on the dish, and both have been in the room several hours, and therefore are about the temperature of the room. We put the button on the thermopile, or the face of the thermopile on the dish, and we obtain in both cases but a very small deflection of the needle,* generally in the direction of cold (§ 195). Before proceeding further we protect the face of the thermopile by

* These and subsequent experiments are made with the galvanometer, as Fig. 6, and not by the reflecting galvanometer; and the former is quite equal to the experiments.

placing on it a piece of thin tin foil; this prevents any moisture affecting the thermopile, which would be the case unless we protected it in some manner. We have also a bottle of water, carefully stoppered; this has been near the dish for hours, and may be taken as the same temperature as the button and the dish. We now proceed with our experiment. We first take the button and *once* rub it across the bottom of the dish, and then present the button to the thermopile. We immediately have a considerable deflection, shown by the needle of the galvanometer, of Heat. Here we have muscular force—kinetic energy, as it is called—converted into Heat, and it will be found by experiment the more we rub the button the hotter it gets. So far so good. This is in harmony with the kinetic theory, and much is made of this experiment in various forms. We now let the button and the dish get as near as possible to the temperature of the room, and then we pour water out of the stoppered bottle into the dish, and fill it about ½ inch deep. We test the temperature of the water by placing the button in the water and then on the thermopile; at first we hardly get any deflection, but after a short time we again dip the button into the water and place it on the thermopile; there is a marked deflection in the direction of cold, showing that the water is evaporating (§ 188). Now we rub the button, which is fully covered by the water, with *more pressure* than we did when the dish was dry, and we go on rubbing and rubbing, for say 200 more times than we did when we *once* passed the button across

the dish—we are expending energy—force, the arm is getting tired; there is no question as to the ratio of force expended in this experiment and the previous one, the *once* drawing the button across the dish. We now present the button to the thermopile, and what is the result? A marked deflection of cold! * These two experiments clearly prove that the development of Heat is not *pro rata* to the force exercised. It will be objected by the kinetic theorists we have in the latter reaction the removal of friction; but immediately arises the question: What is meant by friction when the concept is applied to the atomic theory? The water consists of molecules, the button moves them—that is all which takes place. If the motion, and motion only, of molecules be Heat, surely the experiment should give the reaction of Heat. Arguing from a similar experiment, Dr. Tyndall says:—

"By the force of the hand, as we have seen, the resist-"ance between the excited poles can be overcome and the "medal turned round. Force is thus expended—what "becomes of that force? It is converted into heat. . . . "the heat developed ultimately is the exact equivalent of "the power employed." †

Now paraphrase his words, and apply the muscular force exercised in our last experiment to the concept. See how it reads!

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* In these experiments with liquids and the thermopile, it is necessary, after each experiment, to carefully absorb the fluid from off the face of the thermopile; it is best done with a soft duster.

† "Heat: A Mode of Motion" (9th edition), 1892, p. 77.

"By the force of the hand, as we have seen, the resist-
"ance between the button and the dish is overcome, and
"the button is forced to move with pressure over the face
"of the dish. Force is thus expended. What becomes of
"that force? It is converted into—what?—cold! But,"
says Dr. Tyndall, "the heat developed is the exact
"equivalent to the power employed."

Please, Mr. Physicist, find the equivalent in Heat—we cannot.*

Now for the true explanation: as the button passes over the dry dish in the first experiment, there exists between the button and the dish vesicles of ether—air molecules. Take a hollow india-rubber ball with a small hole in it; if we press that ball quite flat, we press the air out. So do we press out the ether from the molecules between the button and the dish, and the button thus seizes the ether from the molecules one after the other, as by the pressure of the button on the dish they become flattened. The button thus becomes surcharged with ether, *i.e.*, the ether "soaks in," and the molecules of the button thus become larger.

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* "FIRST LAW OF THERMO-DYNAMICS.—Whenever work is performed by the agency of heat, an amount of heat disappears equivalent to the work performed; and whenever mechanical work is spent in generating heat, the heat generated is equivalent to the work thus spent. . . . This is called the *first law of thermo-dynamics*, and it is a particular case of the great natural law . . . which asserts that energy may be transmuted, but is never created or destroyed."—"Elementary Treatise on Natural Philosophy," Part II., Heat, by A. P. Deschanel, edited by Professor Everett (11th edition), 1889, p. 462.

When the button is presented to the thermopile, it gives out the ether which has "soaked in," and the galvanometer registers plus ether—Heat. But when the button presses upon the very minute water molecules, which are nearly solid spheres and contain little ether, the air molecules were displaced by the water molecules; hence the gaseous molecules do not exist between the button and the dish (or, at least, only in a small proportion, and then the gases are in a liquid condition); there could not, therefore, be ether enough to be seized by the button, and consequently, the water being at a lower temperature than the air, the reaction on the galvanometer is that of cold. The water molecules, being nearly solid spheres, acted as so many ball bearings.

197. But continue the rubbing of the button in the water, and it will be found the more we do work the less will be the deflection of the needle to cold. How is this? Because the motion of the button in the water causes such commotion in the molecules that they entrap and absorb an amount of the superincumbent air molecules, which become mixed with and compressed by the pressure of the water (§ 169), and thereby they give out ether to the water and the button, and the latter becomes gradually, very slowly, increased in temperature. This increase of temperature exceeds the cold or loss of temperature by evaporation. Now we can understand Joule's and Count Rumford's experiments. All their experiments were made in air, and the heat obtained was

by pressing the ether out of the air molecules—molecule after molecule—hence was obtained the natural law that the ether accumulated is in proportion to the energy or force exercised; but exclude the air molecules and substitute oil molecules, under the conditions the engineer does, and the whole concept given tumbles to pieces. The ratio of work to the development of Heat depends entirely upon the material operated on. We cannot deduce a general law from one experiment. We may obtain a law which may be of highest value to the specialist—the engineer; and this Joule has done. We can go no further. The physicist, however, wants to make this one law cover all phenomena. Here is his error.*

* There is not a work on Heat which does not quote the experiments of Count Rumford. We will quote Dr. Tyndall ("Heat: A Mode of Motion" (9th edition), 1892, p. 41): "He" (Count Rumford) "then designed a gun-metal cylinder for the express purpose of generating heat by friction. A blunt rectangular piece of hardened steel, "called by Rumford a borer, was forced edgeways against the solid "bottom of the cylinder, while the latter was turned round its axis by "the force of horses. To measure the heat developed, a small round "hole was bored in the cylinder, into which was introduced a small "mercurial thermometer. The weight of the cylinder was 113·13 lbs. "avoirdupois. The borer was 0·63 of an inch thick, 4 inches long, "and nearly as wide as the cavity of the bore of the cylinder, namely, "$3\frac{1}{2}$ inches. The area of the surface by which its end was in contact "with the bottom of the bore was therefore nearly $2\frac{1}{3}$ inches. At the "beginning of the experiment the temperature of the air in the "shade, and also that of the cylinder, was 60° F. At the end of 30 "minutes, after the cylinder had made 960 revolutions round its axis, "the temperature was found to be 130°." . . . "Rumford next sur-"rounded his cylinder by an oblong deal box, so that the cylinder

A complete proof that the Heat is obtained from the air molecules in our last experiment is shown thus: fill the dish with olive or sperm oil, or, better, any well-reputed lubricating oil—it is a well-known fact a lubricant overcomes what is called friction. Let the button rest in the lubricant some time. On presenting the button to the thermopile, the galvanometer gives a slight reaction (generally of Heat, but sometimes Cold) (§ 195). Now rub the button in the oil on the bottom of the porcelain dish, say one hundred times each way, backwards and forwards, and we obtain the reaction of Heat as we did in the water

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" could turn water-tight in the eentre of the box, while the borer was " pressed against the bottom of the cylinder. The box was filled with " water until the entire eylinder was eovered, and then the apparatus " was set in action. The temperature of the water on eommencing " was 60° Fahr.

" 'The result of this beautiful experiment,' writes Rumford, 'was " 'very striking, and the pleasure it afforded me amply repaid me for all " 'the trouble I had had in contriving and arranging the complicated " 'machinery used in making it. The cylinder had been in motion " 'but a short time, when I perceived, by putting my hand into the " 'water, and touching the outside of the cylinder, that heat was " 'generated. At the end of one hour the fluid, which weighed 18·77 " 'lbs., or 2½ gallons, had its temperature raised 47 degrees, being now " '107 degrees.' " . . . " 'At two hours and twenty minutes it was " '200 degrces; and at two hours and thirty minutes it ACTUALLY " 'BOILED!' "

Had Count Rumford filled the cylinder with oil, he might have expended foree to any extent, and the results would have not raised the temperature of the water. The crror of Count Rumford is now readily seen; he omitted to takc notice of the important faetor—thc air molecules; it was from thcm he obtained the cther, whieh appeared in thc form of Heat. Our experimcnts clearly explain thc issue.

(§ 197). But we saw there was practically no evaporation of the oil (§ 191). Hence we obtain a greater reaction of Heat than we did in the water. The more viscid the lubricant is, the greater is the reaction of Heat in proportion to the force exercised—this is a necessary consequence, proven by experiment, and completely demonstrates the kinetic theory to be false. Why then does the engineer, when using lubricants, fail to get a marked evolution of Heat? Because he uses his lubricant in such a way that there is no motion on the surface of the fluid. Hence he prevents the absorption of the superincumbent air molecules. Now in our experiments, because a shallow dish is used, a great surface is exposed to the air-molecules, which we must remember are pressing on the surface equal to about 15-lbs. to the square inch; the motion of the button causes great commotion in the oil molecules, thereby they entrap, as it were, the air molecules and contract them to the liquid condition; thus they give out ether and warm the oil; but as the button is nearest to this commotion of the molecules, being its cause, it gets the greater amount of ether. This is proved by the fact that if we let the button remain in the oil a short time after the experiment is made, and then present the button to the thermopile, we obtain a slight reaction of Heat, but not such a deflection of the needle of the galvanometer as we obtained immediately after the rubbing of the button in the oil. The slight deflection of the needle shows the rise of temperature in the oil. It may here be noticed

no thermometer is of any use in these experiments—it is a coarse instrument.

198. The development of Heat is not in the ratio to the force expended (§ 196).

Consider the following: Take hard brittle steel and soft iron or steel; submit them to tensile strain. The hard steel will break off short, without contracting, and there is no evolution of Heat (as tested by the thermometer). Now try the experiment with the softer material, and it will thin out like a piece of putty and break; where it thins out it is heated, or, better expressed, a considerable evolution of ether takes place. Notice the hard steel, if it is a good specimen, took much more force to break it than the soft iron did. Heat, therefore, is not in a ratio to the force expendid.

The following (Figs. 82 and 83) show the specimens operated on :—

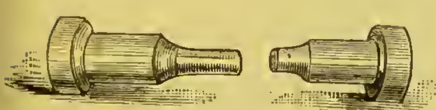

Fig. 82.
Hard steel broken, temperature not altered.

Fig. 83.
Soft iron thinned out and broken, temperature raised, where the iron contracted.

Of four specimens of hard steel, all broke without contraction and no rise of temperature; one specimen stood the strain of 53 tons per square inch. Of six specimens of the soft iron, the average strain was only 24 tons per square inch, and the rise of temperature was over $14\frac{1}{2}$° Fahr.

In the hard brittle steel the molecules parted without displacement, but in the soft iron molecular displacement took place, and thus pressed on the gaseous molecules which were between the molecules of the solid; the gaseous molecules thus gave out their ether, which was absorbed by the solid molecules, and the latter was raised in temperature. These gases were necessarily inter-molecular, from the conditions by which the metal was extracted from the ore. It is the button experiment (§ 196) under another form, or the fire syringe experiment (§ 134) illustrated in another way.

Every knock of the hammer on the soft nail, every compression from the rivetting machines, every abrasion from the planing and tooling machines produces the same effect. Savages learnt to get fire by simply pressing ether from the gaseous molecule, or from the gases in the solids. The view is strictly harmonious with all phenomena seen in our daily life.

199. Let us consider the following: we will take the engraving from "Deschanel's Heat":—

"A piece of ice is placed at the bottom of a glass "tube" (Fig. 84) "which is then partly filled with water; "heat is applied to the middle of the tube, and the upper "portion of the water is readily raised to ebullition, "without melting the ice below."* The better experiment

* "Deschanel's Natural Philosophy," Part II., Heat (11th edition), 1889, p. 422.

is with a short mercury thermometer, the bulb of which reaches the bottom of the glass tube—it is more delicate—the mercury in the thermometer does not rise, and why? Because the molecules of water become larger at the top, being super-saturated with ether, and therefore specifically lighter, and cannot descend below the smaller, cold

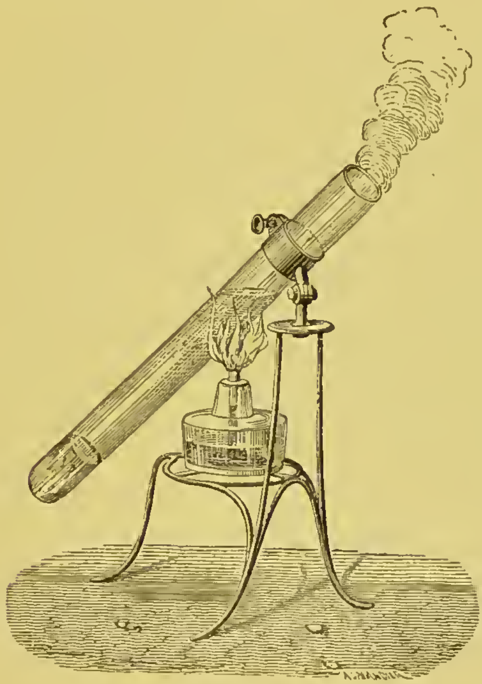

Fig. 84.

molecules. How simple and clear is the explanation of the reaction! Compare it with the poor and feeble explanation given by the physicist. This is all the explanation Deschanel gives: "The following experiment is "one instance of the very feeble conducting power of "water." And then he explains the experiment in the words we have given. What is meant by "conduction"?

He says, page 412, "This transmission of Heat is called "*conduction*." This is all he can say. How can conduction take place without having something to be conducted? How can transmission take place without having something to be transmitted? Yet the physicists' concept is otherwise! They use words, mere words, which have no logical meaning!

200. Consider the expression of Deschanel, "the very "feeble conducting power of water";* as a matter of fact, water is one of the best conductors for practical purposes we have! Yet the physicist calls it a "feeble conductor"! All our appliances for heating by fluids is done by water. To say this process of conveying ether, and we call it Heat, is not conduction, is to quarrel about mere words. To prove this power of conveying ether, Deschanel gives a section of a building showing the furnace, the boiler and pipes, etc., and all the explanation of the reactions he can give are embodied in these words: "When different "parts of a liquid or gas are heated to different tem-"peratures, corresponding differences of density arise, "leading usually to the formation of currents. This

* Probably the following pertinent experiment best shows up the error of the physicist when he calls water a "feeble conductor:"—Put a kettle of water on a bright fire; it soon boils, and the heat is conducted away by means of the water. Empty the kettle and then repeat the experiment—the bottom of the kettle soon disappears! What is the difference between the two experiments? Simply the remarkable conductivity of the water molecules.

"phenomenon is called *convection*." * Now "convection" is only "conduction" of ether by objects free to move with a change of ether.

This is all, then, Deschanel can tell us of "convection." It is but a statement of fact—it is no explanation. It is very much like a man accepting a bill and shaking his knowing head and saying, "That bill is paid, am I "not clever?" A day must come, in the natural order of things, when this mental bill, accepted by the physicist, must be paid, and then the shortcomings of the physicists become apparent.

201. Well, then, consider the circulation of water by which our houses are heated. It is nothing else but a modification of the principles of distillation. The liquid is not converted into the vapour, and then pressed into a worm or cooler, but the same simple principle exists.

The circulating pipes (which are analogous to the distiller's worm) are kept filled with water, while in distillation the worm is more nearly kept filled with vapour or gaseous molecules super-saturated with ether. Here is really the essential difference in the two processes. As the water molecules absorb the ether and travel along the pipes by their temporarily holding the ether, they are relatively lighter than those which hold less of this ether. Those which hold the most ether tend to rise to the

* "Deschanel's Natural Philosophy," Part II., Heat (11th edition), 1889, p. 295.

highest point of the circulating apparatus. As they rise thus charged with ether they surrender the ether to the iron pipes, the molecules of which in their turn surrender the ether to the air, and it thereby becomes charged with ether, *i.e.*, warmed. The whole art in making this apparatus is to allow the lighter molecule to ascend to the position required with the least resistance, and the smaller or so-called denser molecule to fall back into the boiler with the least resistance. Thus, during the passage from the boiler to the highest point, the molecule becomes a common carrier of this important fluid —ether. In the process under consideration the air absorbs ether, thus each molecule becomes increased in dimensions—*i.e.*, the temperature increased. We put a thermometer in the room, the molecules in the bulb take a relative proportion of the ether and the quicksilver rises, and we say the room is of a higher temperature; we feel the increase of ether in our bodies, and we say the room is warm! This is all. It is extremely simple, but compare the explanation to that given by the physicist! Indeed, what real explanation is given? Why, it is absolutely *nil*. The ignorance of the physicist is covered by high-sounding, incomprehensible words or symbols (§ 28).

202. The comparison between the distillation and heating of spaces—rooms, by fluids surcharged with ether approaches much nearer if, instead of heating by means of hot water, we heat by steam. Here then the process is exactly the same as in distillation, with this exception:

instead of draining away the ether given out by the molecules super-saturated by ether to cold water as in the worm tub or cooler, it gives the ether out to the cold air. The process now is easily understood.

203. In § 186 we have shown that on looking at the minute groups of water molecules by means of the microscope, we can see them suddenly spring into the gaseous condition and disappear. The following apparatus (Fig. 85) shows this same process going on in a very interesting way, but in a different manner. The experiment of seeing liquid molecules spring from the metal plate to the gaseous condition and thus disappear, from a philosophical point of view, is the more important, but from a practical point of view the following experiment is the more instructive. As we take the engraving from Deschanel's "Heat," we may as well take the description from the same source. We shall correct the errors of expression after the case has been stated by the physicist.

"*Pressure of Vapours. Maximum Pressure and Density.*—"The characteristic property of gases is the elastic force*

* Foot-note by Deschanel: "The terms 'pressure,' 'tension,' "and 'elastic force' are often used interchangeably to denote the "stress existing in a vapour or gas. 'Tension' is the ordinary term "employed in this sense in French books. The best English authorities "upon elasticity, however, employ the two terms 'pressure' and "'tension' to denote two opposite things; a pressure is a push, and a "tension is a pull. Gases and vapours cannot pull, they can only "push, and they are constantly pushing in all directions; hence they "are never in a state of *tension*, but are always in a state of pressure." What confusion the physicist has to confess to! Here, it will be ob-

"with which they tend to expand.* This may be exempli-
"fied in the case of vapours by the following experiment.

"A glass globe A" (Fig. 85) "is fitted with a metal

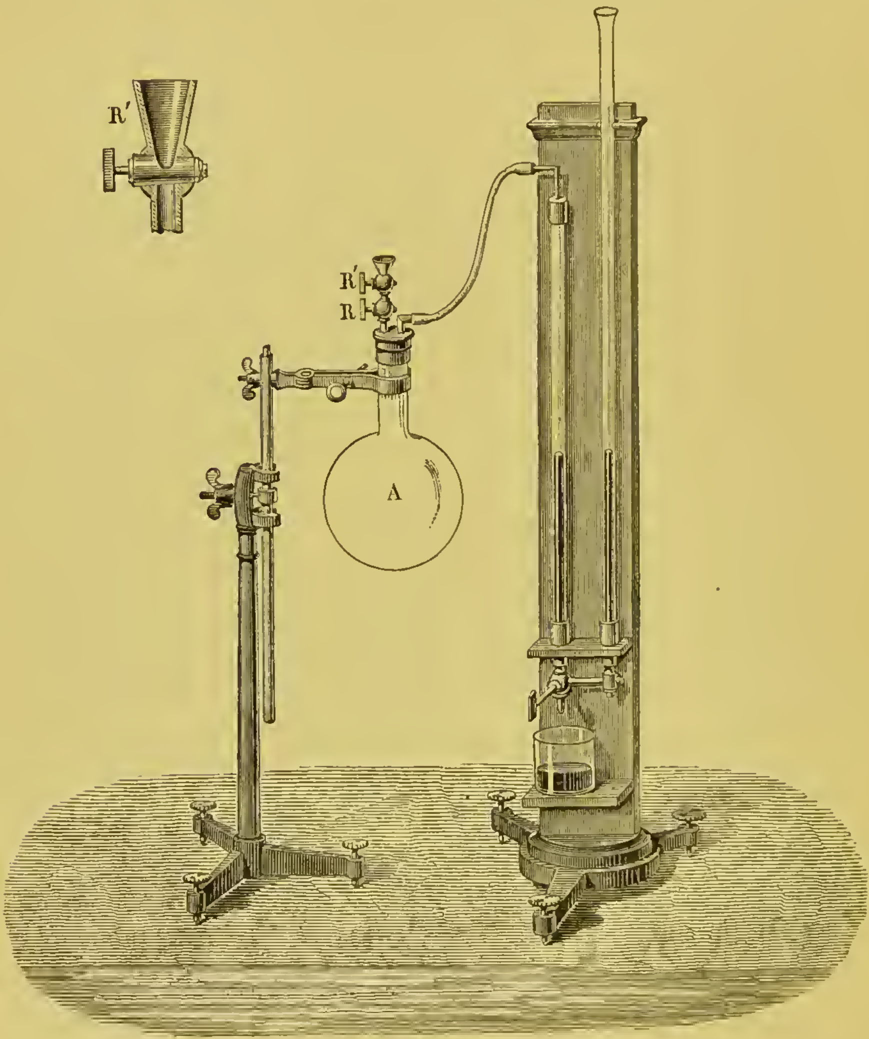

Fig. 85.

served, Deschanel is intuitively conveying the concept we have given of a sphere tending to increase in dimensions. This tendency is the push in "all directions."

* The words, "elastic force, by which they tend to expand," applied to the individual atom or molecule, interprets the concept we have given.

"cap provided with two openings, one of which can be "made to communicate with a mercurial manometer, "while the other is furnished with a stop-cock R. The "globe is first exhausted of air by establishing communi-"cation through R with an air pump. The mercury rises "in the left-hand and falls in the right-hand branch of the "manometer; the final difference of level in the two "branches differing from the height of the barometer only "by the very small quantity representing the pressure of "the air left behind by the machine. The stop-cock R is "then closed, and a second stop-cock R′, surmounted by a "funnel, is fixed above it. The hole in this second stop-"cock, instead of going quite through the metal, extends "only half-way, so as merely to form a cavity. This cavity "serves to introduce a liquid into the globe, without any "communication taking place between the globe and the "external air. For this purpose we have only to fill the "funnel with a liquid, to open the cock R, and to turn "that at R′ backwards and forwards several times. It "will be found that after the introduction of a small "quantity of liquid into the globe, the mercurial column "begins to descend in the left branch of the manometer, "thus indicating an increase of elastic force. This elastic "force goes on increasing as a greater quantity of liquid "is introduced into the globe; and as no liquid is visible "in the globe, we must infer that it evaporates as fast "as it is introduced, and that the fall of the mercurial "column is caused by the elastic force of the vapour "thus formed. This increase of pressure, however, does "not go on indefinitely. After a time the difference of level "in the two branches of the manometer ceases to increase, "and a little of the unevaporated liquid may be seen in the "globe, which increases in quantity as more liquid is "introduced. From this important experiment we con-

"clude that there is a limit to the quantity of vapour which "can be formed at a given temperature in an empty space. "When this limit is reached, the space is said to be "*saturated*, and the vapour then contained in it is at

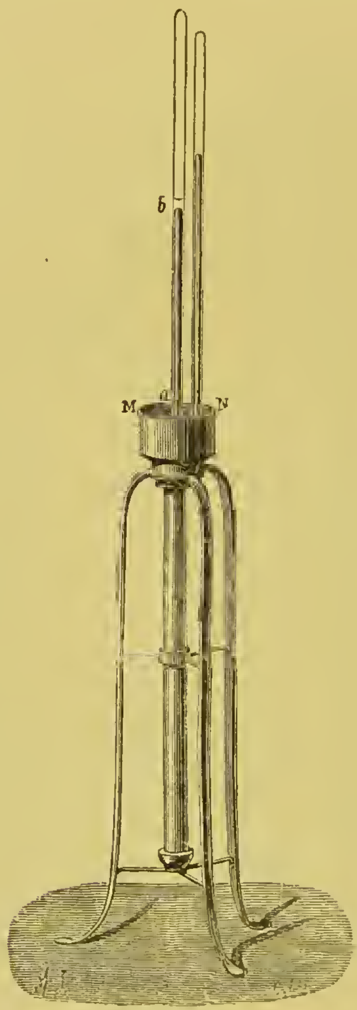

Fig. 86.

"*maximum pressure* and at *maximum density*. It evidently "follows from this that if a quantity of vapour at less than "its maximum density be inclosed in a given space, and "then compressed at constant temperature, its pressure "and density will increase at first, but that after a time a

"point will be reached when further compression, instead "of increasing the density and pressure of the vapour, "will only cause some of it to pass into the liquid "state. This last result may be directly verified by the "following experiment. A barometric tube *a b*" (Fig. 86) "is filled with mercury, with the exception of a small space, "into which a few drops of ether are introduced, care "having first been taken to expel any bubbles of air which "may have remained adhering to the mercury. The tube "is then inverted in the deep bowl M N, when the ether "ascends to the surface of the mercury, is there converted "into vapour, and produces a sensible depression of the "mercurial column. If the quantity of ether be sufficiently "small, and if the tube be kept sufficiently high, no liquid will "be perceived in the space above the mercury; this space, "in fact, is not saturated. The pressure of the vapour which "occupies it is given by the difference between the height of "the column in the tube and of a barometer placed beside it. "If the tube be gradually lowered, this difference will at first "be seen to increase, that is, the pressure of the vapour of "ether increases; but if we continue the process, a portion "of liquid ether will be observed to collect above the "mercury, and after this, if we lower the tube any further, "the height of the mercury in it remains invariable. The "only effect is to increase the quantity of liquid deposited "from the vapour." In a foot-note, Deschanel adds: "Strictly speaking, there will be a slight additional de- "pression of the mercurial column due to the weight of "the liquid thus deposited on its summit; but this effect "will generally be very small, owing to the smallness of the "quantity of liquid." *

* "Elementary Treatise on Natural Philosophy," Part II., Heat, by A. Privat Deschanel, edited by Prof. J. D. Everett (11th edition), 1889, pp. 338 to 340.

Now, these very important and instructive experiments are incomplete; they tell the truth so far, but by no means the whole truth. We proceed to fill up the gaps, and to fully explain the reactions. Deschanel does not, as usual, give the explanations; he only flounders amongst terms which evidently are not definite, for this the foot-note confesses. To complete Fig. 85 there should be a thermo-electric pile inserted in the globe A, just below the stop-cock R connected with the galvanometer (as we have illustrated in the apparatus, Fig. 53). Now the apparatus would be complete.

The liquid is inserted into R′, and, drop by drop, it either falls upon the thermopile and there quickly vanishes by the absorption of ether, or does so just before it reaches the thermopile, exactly as our groups of molecules expanded from the metal (§ 186). Now what is the consequence? The water molecules, as they expand, rob the thermopile of ether—it becomes chilled, and the galvanometer registers the reaction of cold.

204. In Fig. 86 there should be inserted in the top of the tube a thermo-electric pair (§ 144), connected, of course, with the galvanometer. When the tube is depressed, the galvanometer would record the reaction of Heat; when it is raised, it would record the reaction of cold. Why? Because, in depressing the tube, the gaseous molecules would by pressure give out their ether, and, as it is termed, warm the pair; while, when we raise the tube,

they would expand and absorb the ether; the pair would then give out ether, and the galvanometer would record the reaction—cold.

205. But there is another reaction with the latter apparatus (Fig. 86) Deschanel entirely overlooks, and it is this: When the tube is *suddenly* raised, there appears in the tube a cloud exactly as seen in experiment (§ 158). We have explained that this cloud is caused by some of the more favoured gaseous molecules absorbing the ether from the less favoured, because of their relative positions. Those which gain the ether become expanded; those which lose the ether contract to the liquid condition; then the latter group themselves together, and become groups of liquid molecules, which can be seen by the means of the microscope (§ 159). These groups are the objects which form the cloud. The experiment is best shown with carbon bisulphide, as it shows the cloud in a very marked way. The groups of molecules being formed and the tube kept raised, the ether soon becomes equally distributed amongst the molecules, and the reaction ceases to be visible—that is, the molecules become of the same dimensions. Thus Avogadro's law is maintained.

206. We now consider a very interesting apparatus, called the water-hammer. It consists of a tube, with a bulb at one end and contracted to a neck. Fig. 87 represents the apparatus.

It is partly filled with water from which air has been expelled. The instrument is made thus: the water is boiled in the tube by means of a fire. During this process the bulb is uppermost. The air molecules seize the free ether arising from the products of combustion (§ 170), they are pressed upwards through a small hole which existed at *c*. By continued boiling the whole or nearly the whole of the air is expelled, and the apparently empty space is filled with only water molecules, super-saturated with ether—steam. When this condition is arrived at, the orifice *c* is sealed by means of the blow-pipe. The apparatus is allowed to cool. What is the result? Now the tube holds only solid water molecules—hard spheres, and water molecules saturated with ether — water gas * — elastic vesicles of ether.

Fig. 87.

Consider the behaviour of this remarkable instrument. If we lift it suddenly up, the water rises from the bottom, and then falls by gravitation with a loud report like a hammer falling upon an anvil—hence its name, the "water-hammer." In water under ordinary conditions air molecules tend to separate these nearly solid spheres, but here are water molecules devoid of air, or nearly so. We have, however, these almost

* This term, which is given for the water molecule in the gaseous form, must not be confounded with the "water gas" of commerce, COH_2.

infinitely minute spheres not packed together in the closest manner, but packed like the seeds in the measure (§ 164). We take the instrument with the bulb downwards, and gently hit the upper part with the hand (Fig. 88).

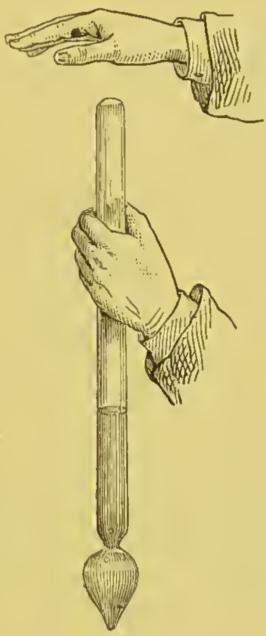

Fig. 88.

Remark the jingling noise, and also notice in the bulb that we can see the molecules momentarily separating from each other; these spaces flash into existence and almost instantly disappear! Presently a time comes when these molecules become, as did our seeds in the measure, more closely packed together—the motion of the molecules and the noise cease. It is very instructive to hear and see the gradual packing of these molecules together. Now invert the water-hammer. The water molecules are so closely packed together, by their mutual attraction, that

the water ceases to be attracted to the earth! The bulb remains quite full. This is very wonderful, and quite in harmony with the concepts we have given. We now hold the water-hammer obliquely in the right hand *above*

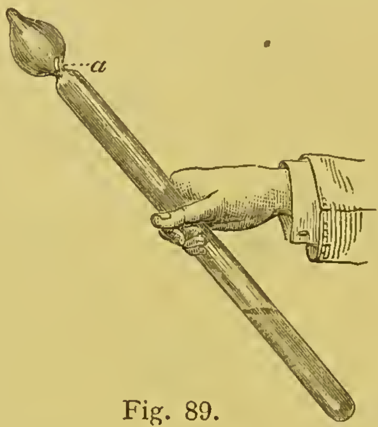

Fig. 89.

the liquid, and gently tap the tube with the left hand. Presently the molecules in the bulb become loose, and the gaseous water molecules will seize the ether coming out of the hand; they will rise in the tube and displace some of the water molecules in the bulb, and as they pass through the neck they form a continuous cone-like mass, just as ether is seen arising from the bottom of the water when about to boil (§ 170), and at the same time the gaseous molecules make the same noise as water when about to boil, and thus the cold water sings! As the gaseous water molecules rise up into the liquid water molecules, they decrease in volume—*i.e.*, lose ether; the water absorbs the ether, or, as it is called, becomes "warm."

207. A tube having two bulbs, partly filled with water, is made in the same way as the water-hammer, so that

it holds only water and water gas, and it is called the Cryophorus. The empty tube A, or rather the bulb containing water gas, is immersed in a freezing mixture (Fig. 90), and the cold crystals of salt and snow melt by the absorption of the ether (§ 181), and take ether from the water molecules in the gaseous form in the so-called

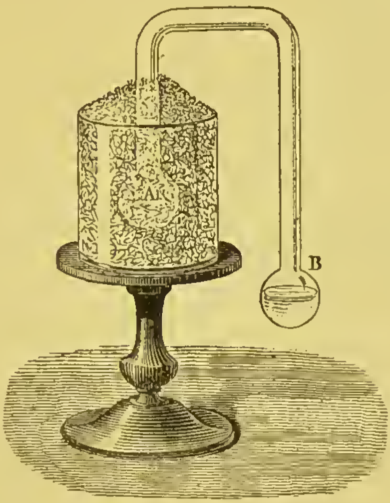

Fig. 90.*

empty bulb; a current of ether is set up from B to A, and it is so energetic that it robs the water in B of the very small amount of latent ether it holds, and the water in the bulb B becomes ice. Here, again, the concept we have given holds good.

208. We put water into a test tube, and it into a vessel containing liquid ether, which has a great affinity for

* The engravings (Figs. 90, 91, 92) are, by kind permission, from "Deschanel's Natural Philosophy," Part II., "Heat."

the fluid we have also called ether, and, with a pair of bellows as illustrated (Fig. 91)—or better, by means of a foot-blower, by which we obtain a continuous current of air through the liquid ether—the ether becomes quickly evaporated, and as the molecules leave the mass they expand and absorb ether so fast that they rob the water

Fig. 91.

of its small amount of latent ether, and the water becomes ice.* Again our concept holds good.

Mercury can be frozen in a similar manner. It can even be frozen in a red-hot crucible by experimentally following out the ideas we have enunciated.†

* Here note, energy—force, is converted into cold! § 196.

† "Heat: A Mode of Motion" (9th edition), 1892, p. 205.

209. So, again, can we freeze water, by placing it in a shallow saucer over a vessel of sulphuric acid, the whole under the receiver of the air pump; when the air is exhausted the sulphuric acid absorbs the water-gas molecules as they spring or jump off the surface of the water in the saucer (§ § 186, 189), and thus the evaporation is so rapid that the residual water molecules change their state. They become angular molecules, crystals—ice (§ 180).

210. We have seen that water boils (§ 173) when it has received a certain current of free ether; it will naturally be inferred that this ebullition is governed by the pressure on the surface of the water. This pressure of the air on the surface of the earth is equal to about 15 lbs. to the square inch. Now, if we remove this pressure, ebullition takes place much quicker than if the pressure existed; hence, in the water-hammer (§ 206), the Heat of the hand is sufficient to cause ebullition in the cold water. The reaction is illustrated in the following way:—

"A little water," says Deschanel, "is boiled in a flask "for a sufficient time to expel most of the air contained in "it. The flask is then removed from the source of heat, "and is at the same time securely corked. To render the "exclusion of air still more certain, it may be inverted with "the corked end immersed in water which has been boiled. "Ebullition ceases also immediately; but if cold water "be now poured over the vessel, or, better still, if ice be "applied to it, the liquid again begins to boil, and "continues to do so for a considerable time. This fact "may easily be explained: the contact of the cold water

"or the ice lowers the temperature and pressure of the "steam in the flask, and the decrease of pressure causes "the renewal of ebullition." *

Now in this explanation all depends upon the concept of what is meant by "temperature." † Deschanel, in defining the meaning of temperature, gives no definition

Fig. 92.

we can grasp; he only shows that certain ratios of one class of matter to another is called difference of temperature. Dr. Tyndall does the same; all text-books follow each other, none have arrived at the notion that the dimension of the atom or molecule is temperature. In the

* "Deschanel's Natural Philosophy" (11th edition), 1889, p. 358.

† "There are few scientific terms more difficult to define than this common word temperature."—"The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition), 1892, p. 39.

case under consideration, the large water molecules supersaturated with ether contract, give out their ether to the cold water molecules which are flowing over the flask, and as they become reduced in dimensions they release the pressure of molecule on molecule—stress. The reaction is simple.

211. So also if we allow water to boil, and then put the hot water under the air pump and exhaust, violent ebullition immediately takes place. But here we must note an important fact. Although the water is in a state of ebullition, the whole of the bubbles of gas ascend or tend to ascend from the bottom of the flask, even although there is no free ether arising from a flame below. To understand this great and important phenomenon, we must explain another interesting experiment.

212. Place the copper bowl (§ 188) on the thermopile, and allow the needle of the galvanometer to get to zero. Uncork a bottle of soda water which has been in the room near the thermopile a long time, so that it is at the temperature of the air, and partly fill the bowl with the water. Everyone knows the very pretty evolution of gas from the midst of the fluid. But these gases almost wholly come from the bottom of the bowl. The molecules of liquid (carbonic acid gas), as they expand to become gaseous molecules, get their ether from the nearest source—in this case, the thermopile. This is placed at the lowest point, and the needle of the galvanometer gives the reaction of cold. So also does

the boiling water under the receiver obtain the ether from the lowest point, and this is harmonious with the fact that ether always tends to rise (§ 91). In a word, it is an antigravitating fluid.

213. The evidence tends to the concept that there is a limit to the expansion of the atom—certainly under a constant external temperature. Thus take a thermometer tube with a large bulb, and with a fine tube open at the end, put into the tube a minute pellet of mercury: this we can easily do when the bulb is hot by dipping the tube into mercury. When it is cold the pellet will go down the tube nearly to the bulb by the contraction of the gaseous entities in the bulb and tube. Now at the temperature of the air place the tube under the air pump and exhaust; the air expands in the bulb, the mercury pellet rises, but will not get forced out by the expanding air atoms and molecules. If, however, under the pressure of the air the bulb is heated as when we inserted the mercury pellet, the expanding air will force out the pellet.

214. Also we note that with fluids pressure has little effect. Thus, if we fill our thermometer tube up to a certain point with distilled water or water free from gaseous matter, and place it under the air pump, the water will not expand and rise in the tube. Only therefore, the absorption of ether will cause the water molecule to expand, and this is called increase of temperature.

215. The evidence tends to the deduction that atoms and molecules, at least in the liquid condition, are not all of the same dimensions, although in the gaseous conditions they are approximately so.* Hence Avogadro's law is so near the truth that we can accept it as true; but with liquids there is a considerable difference in dimensions of the spheres at a given temperature—that is, with a given quantity of ether distributed amongst them. Consider a quart measure of glass marbles and a quart measure of fine shot. We put the fine shot into the measure of marbles, the shot goes between the marbles and we get by this mixture a volume considerably less than two quarts. In a similar way the following experiment is explained.

Fig. 93.

This apparatus (Fig. 93) consists of a long glass tube *a*, with two bulbs of about equal capacities *b*, the upper one being fitted with a stopper. We fill the tube and lower bulb with water molecules, which, recollect, contain free gases—air molecules, compressed to a liquid condition

* "Formerly it was supposed that all gases expand at the same "rate when heated (Law of Gay-Lussac). This, however, although "approximately true, is not strictly so, and the rate of expansion of "each gas is properly represented by a coefficient which is peculiar "to itself, as is the case with solids and liquids."—"Watts' Manual of "Chemistry," by Prof. William A. Tilden, F.R.S., 2nd edition (14th edition of Fownes), Vol. I., 1889, p. 18.

(§ 170); then we fill the upper bulb with a much lighter material—spirits of wine—which floats upon the water. We carefully insert the stopper so that there is no air in the apparatus—it is quite full of the two liquids. Now invert the apparatus and the smaller spheres get between the larger spheres, the volume of the two becomes reduced, and a space free from liquid is seen at the upper part of the tube. In this reaction the smaller spheres coming between the larger ones displace a quantity of the air molecules, and they rise to the top of the water and fill up the space which would otherwise be a vacuum. The concept of the physicists is: all atoms, at all temperatures and under all conditions, are of constant volume. The assumption—for assumption alone it is—is purely gratuitous and founded upon metaphysical (mathematical) reasoning alone, and it is not borne out by the rigid test of experiment.

Fig. 94.

216. Before we close this chapter we will review the important alterations which molecules assume. It will be noticed there take place three distinct differentiations in the atom or molecule, and each of them is effected by a sort of jump or nearly instantaneous alteration. Our best illustration is water. First, the angular crystalline molecules (ice or snow) by the absorption of ether jump into the spherical condition, then we obtain the liquid. Secondly, the jump of the very small sphere—

the liquid into the gaseous, the much enlarged sphere—the vesicle of ether. This is absolutely seen in § 186. Thirdly, the jump which takes place when the gas entity becomes so enlarged by absorption of ether and the intensity of the internal flow of ether (strain) that it becomes split up into three objects, two hydrogen and one oxygen. These are the three well-marked phases in molecular reactions. Thus, with definite ideas of temperature and the flow of ether, we can understand nearly all, if not all, the phenomena in Nature.

217. The following very interesting experiment, first shown we believe by Mr. Shelford Bidwell, illustrates the direct relation of Heat to Electricity. Stretch a fine iron wire between two upright supports, and connect the two ends with the galvanometer. Now put under the wire a lighted spirit lamp and make the wire red hot: if we cause the light to gradually travel along the wire from one end to the other the incandescent mass is made to travel in a like manner, and the needle in the galvanometer moves in one direction in harmony with the movement of the lamp. Reverse the experiment by causing the lamp to travel in the contrary direction, and the needle of the galvanometer reverses itself and travels also in the contrary direction. When we heat the wire we super-saturate the molecules with ether to such an extent that they are incandescent; by moving the spirit lamp we cause the flow of the ether in one direction,

and the needle responds; reverse the motion and the flow of ether goes in the opposite direction, and the needle gives the response that the flow in the galvanometer is in the contrary direction. The galvanometer shows the current of ether and the direction of the flow.

XIII.

218. We finally invite the reader's careful consideration of the following:—

The concepts of the chemists are, that matter consists of finite objects, called atoms, of constant dimensions, and that when they come sufficiently close together they group themselves into definite groups, and thus form objects called molecules. This is chemical combination. If, however, the objects of which gases are formed be brought so close together that they become liquids, and thus so close that there is a real change of state, we obtain no evidence of chemical reaction! Professor Dewar has recently liquefied air, which consists of, principally, oxygen and nitrogen gases, but there is no evidence of chemical combination. The nitrogen comes off the liquid first, as nitrogen gas, followed by the oxygen, which comes off as oxygen gas. When in the liquid condition the temperature is very low, it is very cold. Now, oxygen and nitrogen combine in five proportions: Nitrous Oxide (gas), Nitric

Oxide (gas), Nitrous Anhydride (liquid), Nitric Peroxide (liquid), and Nitric Anhydride (solid). None of these are formed by bringing the molecules close together, or, as it is called, reducing their temperature. This process alone in no case effects chemical combination; it should do so, however, if the kinetic theory were true. It requires a super-saturation of ether, an excess of temperature or volume of the molecule by the absorption of ether (strain), to cause chemical combination (§ 104, § 117).

219. The concept given in § 117 of atoms and molecules at a certain internal strain of ether or temperature overwrapping each other will be hard to grasp at first; but when the idea is once seized it grows, and it becomes more and more difficult to shake off, because it is the only idea which can be grasped by the human mind to explain the known phenomena; hence the mind gradually gets to believe it is the truth.

220. Chemists, in order to explain chemical combination, regard the results of atoms coming together to make molecules as being a close approach or "bonding" of atoms. The mind has no concept of what "bonding" means. Professor Cooke explains it thus:—

"It is assumed that each of the elementary atoms has "a certain definite number of bonds, and that by these "alone it can be united to other atoms. If you wish to "clothe this abstract idea in a material conception, picture "these bonds as so many hooks, or, what is probably

"nearer the truth, regard them as poles" (§ 104) "like "those of a magnet."*

Now the idea of hooks attached to the atom is a very far-fetched notion; but the mind craves for definite ideas, and a bad one is often a useful temporary one.

The concept is thus graphically pictured to the mind by the chemist:—

$$\begin{array}{cccc} & & | & | \\ \mathrm{H}\,- \quad & \quad -\,\mathrm{O}\,- \quad & \quad -\,\mathrm{N}\,- \quad & \quad -\,\mathrm{C}\,- \\ & & & | \end{array}$$

Where each dash represents the hooks or bonds, the property of the atom. Hence hydrogen (H) has one bond, oxygen (O) has two bonds, nitrogen (N) has three bonds, carbon (C) has four bonds, and this power of bonding in a definite manner is called "quantivalence." Hydrogen is called a monad; oxygen, a diad; nitrogen, a triad; carbon, a tetrad. When we come to combine these elements to form compounds, we have this order of illustration:—

$$\begin{array}{cccc} & & \mathrm{H} & \mathrm{H} \\ & & | & | \\ \mathrm{H-H} \quad & \quad \mathrm{H-O-H} \quad & \quad \mathrm{H-N-H} \quad & \quad \mathrm{H-C-H} \\ & & & | \\ & & & \mathrm{H} \end{array}$$

But, as Professor Cooke properly states:—

"This idea of quantivalence suggests, or, rather, as I "should say, implies the idea that the molecules have a

* "The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition), 1892, p. 265.

"definite structure." He adds, however, the important fact: "The symbols of these molecules indicate an obvious "limitation to this idea of structure."*

Now what is the structure of a liquid molecule—take water H — O — H? Why, all the phenomena indicate it is a very minute sphere (§ 97, § 98); and Prof. Cooke (with chemists and physicists generally) is forced to so regard the liquid molecule. Prof. Cooke properly says, "atoms must "be magnitudes of something."† Whether atoms are constant magnitudes—that is, always of the same form and dimensions, or the *only* alternative of variable form and dimensions, is the crux of the important issue under consideration, and we believe that the evidence is absolutely overwhelming in favour of this last concept. And this evidence becomes the more powerful when we remember that in the higher molecules the complexity is enormous. Now let us consider: Prof. Cooke states—

"Every molecule has a definite structure. It not "only consists of a definite kind and a definite number "of atoms, but these atoms are arranged or grouped "together in a definite order, and it is the great object "of modern chemistry to discover what that grouping "is."‡ Speaking of the element carbon, Prof. Cooke continues: "The number of known compounds of this "one element is far greater than that of all the other "elements besides, and these compounds exhibit a great "diversity in their molecular structure, which is often highly

* *Idem*, pp. 266, 267. † *Idem*, p. 263. ‡ *Idem*, p. 247.

"complex. As a rule they consist of a very few chemical "elements (besides carbon, only hydrogen, oxygen, and "nitrogen), but the number of atoms united in a single "molecule may be very large, sometimes even exceeding "one hundred." *

Indeed, groups of atoms called molecules are often highly complex and consist of a great quantity of atoms, and often these at ordinary temperatures are liquid molecules, and the issue is very clear: Are these molecules spheres or are they not? If the former, then the only concept possible is, they are objects—spheres, created by atoms overwrapping each other under a given flow of ether or internal strain and then contracting to become the very minute liquid object, which alters in dimensions according to the amount of ether held or "soaked in" at any moment of time, and this dimension of the sphere is "temperature."

Once concede this question of atoms over-wrapping each other, then what vastly complex reactions can take place with the definite result that the molecule in the liquid and gaseous conditions is a sphere—why, the number of variations speedily become to the human mind infinite. Consider a molecule—a sphere—built up of three atoms, call the atoms A, B, C. Let us suppose that in the order of Nature, the process is as follows: Under a given internal and excessive pressure of ether,

* *Idem*, p. 322.

C overwraps B and A, or B overwraps C and A, etc. Then for only three atoms we may have the following variations :—

	1	2	3	4	5	6
Inner sphere ...	A	A	B	B	C	C
Middle sphere ...	B	C	A	C	A	B
Outer sphere ...	C	B	C	A	B	A

With this order of formation of molecules, let us ask ourselves what are the possible variations in a molecule built up of one hundred atoms? We obtain a number of variations which is enormous. Chemists recognise a condition of things which they call "isomerism," which Professor Cooke calls "a most remarkable phenomenon." * It consists of different molecules of the same density, having totally unlike appearance, giving different properties, but built up of the same atoms. In one grouping the molecule may be food, in another grouping the molecule may be poison! In the illustration above we have the concept of six liquid molecules, each being spheres, all built up of the same three atoms, and the densities of each molecule being the same. Here we obtain the idea of isomerism, and of difference of structure. In treating of this "most remarkable phenomenon," Professor Cooke states :—

"The difference of qualities depends on molecular "structure, and that the same atoms arranged in a different "order may form molecules of different substances having

* *Idem*, p. 324.

"wholly different qualities." . . . "These *isomeric com-* "*pounds,* as we call them, when acted on by chemical "agents, break up in very different ways, and, by studying "the resulting reactions, we are frequently able to infer "that certain groups of atoms (or compound radicals) "are present in the compounds." *

Now regard the illustration, look at the outer sphere as the object which comes off first, and the two internal spheres as the radical. In variation 1 the element C will come off first, and B and A will be the radical. In 2 the element B will come off first, A and C will be the radical, and so forth. This is exactly the reaction the chemists find in experiment. How curiously complete seem the concepts given in this work. Surely, then, they must be true.

221. We have now to consider the function of internal strain, arising from the flow of ether through the atoms or molecules producing the phenomenon known as chemical decomposition or recomposition. The evidence tends to point to the following:—When the flow of ether through the atom or molecule is a certain internal pressure (strain) on atoms and molecules, they combine or overwrap each other; when this internal pressure becomes very high, the molecules then come out of each other—that is, they are decomposed. Consider the following illustration:—

"Pure mercury is quite unalterable in the air at com- "mon temperatures, but when heated to near its boiling

* *Idem,* p. 326.

"point, it slowly absorbs oxygen, and becomes converted "into a crystalline dark-red powder, which is the highest "oxide. At a dull red heat this oxide is again decomposed "into its constituents." *

Or consider the water molecule at a certain great strain arising from the internal pressure of ether: the molecule splits up into oxygen and hydrogen gases. At a lower strain these elementary objects, oxygen and hydrogen gases, overwrap each other—that is combine, give out ether; they form the vapour molecules of water—steam, which in its turn gives off ether to form water in the gaseous form, or ultimately condenses into the liquid water molecule. This important view of this great question wants careful study. It is quite in harmony with the concepts enunciated in this work.

"Thus water, although such a stable compound, is "resolved into a mixture of oxygen and hydrogen gases "at temperatures above 1200°." †

We have seen that whenever matter in mass contracts after chemical combination, we have an evolution of ether, and such reaction is called by the chemist *exothermous* compounds; and when the inverse process takes place—that is, when the volume of matter increases as the result of chemical reaction—we have an absorption of ether

* "Watts' Manual of Chemistry" (2nd edition), by Prof. William A. Tilden, F.R.S., Vol. I., 1889, p. 391.

† "The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition), 1892, p. 389.

producing *endothermous* compounds, and the ether absorbed is called by the chemist the *Heat* of *formation*. How simple and clear is the idea now!

222. We have stated—we think proved—that ether is ever present; that the ether "soaked-in" in certain molecules is the factor which always produces chemical reaction—hence with certain molecules the normal temperature of the air is so near the combining temperature that the merest balance of increase of temperature causes chemical reaction, hence we obtain a class of molecules which, when associated together, combine at ordinary temperature, producing the well-known *unstable compounds*. How difficult is it to grasp the reactions by any other mode of reasoning. Prof. Cooke recognises this:—

"If the tendency in chemical reactions is always to "those products which will determine the greatest evolu-"tion of heat, how does it come to pass, in any case, "that unstable substances should be formed? How is "it possible to pass from elementary substances to what "we have called endothermous compounds; or from exo-"thermous compounds to elementary substances? How, "in an atmosphere of oxygen gas, have organic tissues, "beds of coal, the useful metals, and other combustible "substances, ever been formed or produced? In a word, "how is any chemical reaction possible which involves "an absorption of heat? Such processes, however, are "constantly going on. Coal is the remains of organic "tissues which grew in the early geological ages, and "similar tissues are now growing under the same sunshine "as of old; the useful metals are readily extracted from

"their ores, and highly unstable products, like nitro-glycer-
"ine, are easily obtained by well-known chemical reactions.
"How is this possible? This is one of those questions
"which it is much easier to ask than to answer. Indeed,
"we can not answer it definitely in the present condition
"of our science." *

We venture to assert the answer Prof. Cooke could not obtain is now given.

223. Let us consider the following difficulty of Prof. Cooke:—

"How far does the heat of chemical combination enable
"us to measure the relative attractive force between the
"elementary atoms? Unfortunately, our answer to this
"question must be even less satisfactory than our answer
"to the last." †

And why? Because the result of chemical reaction is here called "heat of chemical combination," that is an "endothermous compound," but when ether is absorbed in chemical reactions we have always an increase of temperature (§ 46), and increase of temperature is the very opposite of "attractive force between the elementary atoms." What a contradiction the following words now appear:—

"A very small excursion of the oxygen and hydrogen
"atoms caused by an increasing temperature might be
"sufficient to bring them within the sphere of their mutual

* "The New Chemistry," by Prof. J. P. Cooke, LL.D. (10th edition), 1892, p. 380.

† *Idem*, p. 383.

"strong attraction, when they would rush together and the "reaction we have written would result." *

With the concepts the kinetic theorists hold, this quotation might be well expressed in the words:—

"When two or more objects are going away from "each other, they are coming close to each other."

Moreover, the physicists regard gases as consisting of molecules always "encountering their neighbours" † and rebounding. When they encounter or impinge on each other they are "within the sphere of their mutual strong "attraction."

The position is impossible—absurd.

224. Yet how close Professor Cooke comes to the truth:—

"We assume that the union of such isolated atoms "is attended with the liberation of heat; and, if so, we "should naturally infer that the effect of heat would be "to part the atoms again. Now, this is exactly what we "find to be true, so far as our experiments extend, and "the effect of heat in parting atoms is what we technically "call 'dissociation.'" ‡

225. Avogadro's law may be taken as true, but it is not strictly true. This is shown by the now known fact expressed thus:—

"Formerly it was supposed that all gases expand at "the same rate when heated (Law of Gay-Lussac). This,

* *Idem*, p. 382. † *Idem*, p. 37. ‡ *Idem*, p. 385.

"however, although approximately true, is not strictly so, "and the rate of expansion of each gas is properly repre- "sented by a coefficient which is peculiar to itself, as is "the case of solids and liquids." *

The granting of this special coefficient of expansion of the gaseous molecule, coupled with the views we have demonstrated, will probably explain diffusion of gases, osmose, and other kindred phenomena, the causes of which were formerly beyond the power of the human mind to understand.

226. We have now exhausted the more important factors solving the great problem: What is Heat?

For the reason given (§ 16) no effort has been made to go into questions of ratios or differences of temperature, or of differences of the current of ether—radiation. When the concept we have given has been fully grasped by the reader, he can obtain all this detail from the various text-books. We have no reason to doubt the truth of these details; indeed, the test to which they are put in our daily experience goes beyond question, and proves the general correctness of these particulars. There is no dearth of these details; what is wanted is such a concept, as we trust we have given, in order to grasp the wonderful phenomena which surround us, as well as the phenomena arising from our own individuality; for, indeed, the same

* "Watts' Manual of Chemistry," by Prof. William A. Tilden, F.R.S. (2nd edition), Vol. I., 1889, p. 18.

laws which govern other matter govern ourselves. To know oneself is the highest aim of man, and we cannot do this until we know the condition of things which surround us. Moreover, we shall see, that the obtaining of this knowledge is the *only method* by which we can minimise human misery. We cannot kick against the laws of nature without suffering.

XIV.

CONCLUSION.

We have now, reader, been travelling, as it were, hand in hand, through a considerable number of phenomena, illustrated by a complete cycle or series of experiments which, if our deductions are correct, are perhaps the most remarkable yet seen by the human eye. Let us take a glance and see how they bear upon our every-day actions in life. Let us suppose we are returning from a walk. It is one of those cold, bitter days we find in these regions. The snow is thawing in the streets—the roadway is covered with slush. The cold wind is blowing; we are cold, as the saying is, "to the very bones." The air is seizing the ether from our bodies faster than it is generated within by chemical reaction, and this is why we feel cold. We enter the house. It is a cheerful English home. The white table cloth laid for dinner, the fire burning in the

grate, and the cat lying asleep before the fire. Having taken off our overcoats, we enter the room and speedily approach the fire. It is giving out ether—the results of chemical reaction. You poke the fire, the fuel is loosened, a mass of flame is the result. You leave the poker in the fire. A greater radiation of ether takes place. We are seated before the fire. The radiation of ether, resulting from the increasing chemical reactions, becomes so great that we are fain to draw away from it. The cat slowly stretches herself and then quietly walks away, perfectly unconscious of the cause of the discomfort—too strong a flow or current of ether; for, to her, the ether is as invisible as it is to us, under these conditions. You take the poker out of the fire—it is red hot. We now know it is exuding this wonderful and all-powerful fluid. Having warmed ourselves, we sit down to the meal. With the dessert, we have some wine. The food, like fuel, as indeed it is, is slowly burning within us, the oxygen is uniting with the food, we are exhaling carbonic acid gas—molecules. The result of the chemical reactions is: we are warmed throughout; the skin is now giving off an increase of ether, partly free and partly as gas—molecules as seen in § 141. The brain, under the influence of the increased nourishment, thinks freely and easily, and we join into conversation somewhat as follows :—

You ask: "Is the case proved?" We reply we do not know. It is more than any human being can affirm. It

must be left for the consideration of that army which exists now, of earnest thinkers who are searching for the truth. All we can say is we *think* the evidence is conclusive. To this mass of earnest thinkers, of which the jury consists, the case is submitted, and we await the verdict.

Bear in mind all we have undertaken is to play the role of the barrister (§ 66), and as becomes this office we have approached the case fearlessly. It may be thought that we have made the case unnecessarily strong against the physicist. Well, we speak from experience. He regards the study of the forces of Nature too much from the commercial point of view, and thus he gets the like contracted ideas too often held by the commercial man ; he sighs that it is not within his power to bottle the air which surrounds the world and sell it at 1s. 1½d. per bottle. It is this excess of commercial instinct which is the curse of the present day. Every thing is to be bought and sold, until the competition of buying and selling has assumed such an acute and anxious form, that the question is raised, "Is life worth living?" Although we speak from sad experience, we know there are many, very many earnest physicists, liberal in mind, sincere in action, but they have been educated in a mental rut, and it was necessary to speak in the strongest terms to get them out of this rut of metaphysics. They may be angry with us. Will history repeat itself? We are right in our deductions or

we are wrong; if the former, the anger will pass away, and our efforts, for our mutual good, will be appreciated. But let us suppose that we have absolutely succeeded. Consider, then, what has been achieved. We have seen that great unknown factor believed hitherto to exist, in a sort of vague way, called "ether," and we have seen that while all other matter tends to fall to the crust of the earth, this indestructible, incompressible fluid tends to rise from the earth, at least in these latitudes. We have, in one case, seen the ultimate molecule; we have seen the vibrations of the molecule, a reaction which Clerk Maxwell evidently sought for when he stated :—

"The evidence for a state of motion, the velocity of "which must far surpass that of a railway train, existing "in bodies which we can place under the strongest "microscope, and in which we can detect nothing but the "most perfect repose, must be of a very cogent nature "before we can admit that heat is essentially motion." (§ 60).

And we have seen the still more extraordinary "nothing" a vacuum! (§ 132). Moreover, for the first time, we have absolutely definite ideas for every term, and these *ideas are all harmonious.* If no mistake has been made, what a progressive step has been effected! It is so grand that it is not a discovery, it is a revelation. A very recent writer properly puts the issue in these words :—

"The nearest way to the heart of the question, how- "ever, lies undoubtedly through the study of the relations

"of matter with heat. Matter, in a sense, lives by heat. "All its transformations are effected, all its activities come "into play, under thermal influence. What, then, would be "the result of its total withdrawal?" *

The reply is: matter then would simply sleep, all the activities would re-arise when ether is brought again to matter, for the evidence appears quite conclusive: matter and ether (which is a form of matter) and the activities of matter, *i.e*, energy, are indestructible, and thus we bow the head in reverence to our surroundings, and realise this grand fundamental fact, that that wonderful Power which exists external to and internal in the human being, alike recognised by *every individual*, and which we may call if we like God—that Power "*is not the God of the dead but the God of the living*."

* "The Liquefaction of Gases." "The Edinburgh Review," No. 368, April, 1894, p. 375.

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